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CONCEPT FORMULATION STUDY FOR AN ARMED AIRCRAFT QUALIFICATION RANGE SCORING SYSTEM

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STUDY, CONCEPT FORMULATION FOR AN ARMED AIRCRAFT QUALIFICATION RANGE SCORING SYSTEM

ABSTRACT

This study examined existing objective scoring devices, scoring systems under development, and possible new techniques, for suitability of application to an Armed Aircraft Qualification Range Scoring System to provide feedback to, and evaluation of, helicopter gunnery students. The current training program, training facilities, and scoring techniques were also evaluated as background information for the study.

Results indicate that scoring systems under development, and most existing scoring devices, are not capable of rapid fire air-to-ground scoring; furthermore, no system delivers vector data on rounds scored. A new technique, the water range concept, has merit as an inexpensive, reliable, maintenance free approach to scoring, but fails to satisfy many specific design requirements. Radar and acoustic systems which depend on a sensor located at the target are unreliable because the sensor is highly susceptible to being destroyed or damaged by the projectiles to be scored. A radar system, which uses a standoff sensor in front of the target, offers the only prospect for a reliable and accurate scoring system. Since the system would not provide vector data, visual observation techniques would also be required to supplement the radar scoring information.

FOREWARD

This report describes the concept formulation work performed under NAVTRADEVCEN Contract N61339-69-C-0179 with Sanders Associates. The purpose of the study was to provide the technical, economic, and military basis for the decision to initiate engineering system development, for a helicopter gunship scoring range.

The basic objectives of the study were to (1) analyze the requirements of the DA approved Small Development Requirement (SDR), (2) examine existing scoring systems in light of the SDR, and (3) propose a hardware system, requiring little research and development, to meet the requirements. The ultimate goal is a reliable, dependable, and versatile scoring system that will provide instant hit information to the attacking helicopter pilot trainee and instructor pilot. The system must perform acceptable regardless of attack angle and azimuth, type of armament selected, and type of target engaged.

The study has revealed that the technology is not sufficiently at hand to meet all of the SDR requirements. The most difficult problem areas to solve are discriminating between the different types of rounds hitting a target simultaneously, and providing a detection system that does not restrict the attack angle and is not susceptible to damage from armament fired into the target area.

Two approaches seem logical at this time: (1) reevaluate the SDR to determine the minimum essential requirements, thereby enabling existing technology to satisfactorily meet the reduced requirements or (2) embark on a research and development effort to ascertain if there is any approach that will meet the existing requirements.

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The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

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SECTION I

INTRODUCTION

A. TECHNICAL BACKGROUND

This document describes the results of a study performed to provide a concept formulation and a performance specification for an Armed Aircraft Qualification Range Scoring System (AAQRSS). The study was performed by Sanders Associates, Inc., Bedford Division, Bedford, Massachusetts for the Naval Training Devices Center (NTDC) Orlando, Florida under Contract No. N61339-69-C-0179. The objective of the study was to analyze state-of-the-art scoring technology and to recommend development of an operational system requiring primarily system design using existing components and without the need for inventions or scientific advances. The selected system or systems are to be used at Army helicopter gunnery ranges to provide scores of the firing runs made by student gunnery pilots using various types of helicopter armament. A scoring system as defined by the Army's Small Development Requirement (SDR) is a system which will consist of a sensing device or devices to detect both hits on a target and near misses, a central display unit for indicating and recording this information, a voice channel to relay scoring data to the helicopter, and realistic targets. The transmission method used between the sensor and central display device and any required signal processing equipment are also considered part of the total scoring system.

The ultimate objective of all Army gunship schools involved in training gunship pilots is to produce the most qualified pilot possible in the shortest time and in the most cost-efficient manner. Factors which influence the overall training program and have direct bearing on this objective are:

* Effective range utilization
* Effective gunship utilization
* Effective ammunition expenditures
* Effective training procedures
* Effective scoring techniques

It is the last mentioned factor to which the study program is primarily addressed. However, with only an introductory understanding of the ultimate objective and its associated problems, it is easily seen that these factors are interrelated. Scoring is needed to evaluate training procedures and student proficiency. Ammunition expenditures and gunship utilization, both of which

directly effect the total cost of training, will increase or decrease depending on the amount of time required for the student to attain the required proficiency. Effective range utilization is related to two factors: (1) the average number of range hours required for a student to attain proficiency, and (2) total usable range time, which is determined by both target and scoring system maintenance requirements. A more detailed analysis and evaluation of each of these factors as they apply to this study will be presented in subsequent sections of this report.

B. PREVIOUS WORK PERTINENT TO THE PROBLEM

For many years scoring technology has been under investigation by the military services and industrial corporations. An Interservice Scorer Technical Group has been established and holds periodic meetings to aid in the exchange of information relating to existing and newly developed scoring technology. While the state-of-the-art of this technology has advanced significantly over the past three decades, a corresponding and perhaps greater growth in new and sophisticated weapons and weapon systems with their associated special scoring requirements, has resulted in a parallel need for special and advanced scoring systems. In some instances, where supposedly adequate scoring methods have been used, disparities between performance data obtained in practice firings and that obtained under combat conditions, have led to increased interest in more valid scoring techniques. As a result, many special studies have been made and continue to be conducted in this area. A possible reason why greater advances have not been made to date is that, although many industrial corporations have had some involvement in scoring technology, very few have had opportunity to engage in much more than a single study or contract; thus any experience or interest gained has not been utilized in the most advantageous manner. The literature search conducted as part of this study has shown that the most significant experience in scoring technology is held by Babcock Electronics Corporation[1], Sanders Associates, Inc.[2] and Del Mar Engineering Laboratories[3]. In addition, Stanford Research Institute has made notable contributions in performance of studies relating to the state-of-the-art of scoring technology; however, they have not been involved in hardware development.

The present study is a direct result of the increasing use of the helicopter as an attack weapon in the southeast Asian conflict. Because of the special problems and terrain in this area, the role of the helicopter has shifted from utility, supply, and rescue missions to include an increased emphasis on

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1. See items 1, 2, 3 and 5, Table 1.
2. See items 27 and 28, Table 1.
3. See items 40 through 44, Table 1.

attack missions. As a result, there has been and will continue to be an increased need for helicopter gunship pilots fully qualified in the use of all helicopter armament systems. This in turn has placed severe burdens on the helicopter gunnery training program in terms of range utilization, training schedules, and training proficiency requirements. As rapid and objective scoring is needed in order to evaluate student performance, the Army has recently installed acoustic scoring systems as an interim measure at both Fort Rucker, Alabama, and Fort Stewart, Georgia. Because of reliability/maintainability difficulties with these systems, scoring is presently being accomplished by the instructor pilot's visual observation. This is regarded as a reliable but inaccurate scoring method. The concept formulation for a new scoring method resulting from this or a companion study, will provide a more accurate and efficient method of solving this special scoring problem.

SECTION II

STATEMENT OF THE PROBLEM

Can a state-of-the-art scoring system consisting primarily of "off-the-shelf" components be procured which will satisfy the following major requirements?

1. Score terminal projectile position with an accuracy of 2 percent at distance from target of from 0 to 15 meters and 10 percent at distance of from 15 to 30 meters, and provide vector information of misses (if development time plus cost is not excessive). If vector information is not provided, the system must record hits on small targets and zone scoring for all targets.

2. Score single or multiple 7.62 and 50 caliber machine guns with individual firing rates up to 6000 spm, 20- and 30-mm cannons with firing rates of 800 spm, 40-mm grenade launchers with firing rates of 220 spm, and rockets with firing rates up to 48 at a time. Also score combinations of these projectiles on consecutive but individual firing runs.

3. Operate reliably in an environment where live ammunition may be used.

4. Require minimum maintenance and calibration.

Although many other requirements are also stated in the SDR, those listed here are the most demanding in terms of a concept formulation. Of primary importance in the operating environment and its effect on survival and maintenance of scoring systems/sensors. Target-mounted sensors, because of their location are inherently highly susceptible to damage or destruction by the projectiles to be scored, especially if live ammunition is used. Even standoff scoring sensors are vulnerable and will require protection from projectiles in the form of a bunker or other type of shielding. If live rather than inert projectiles are used; i.e., a harsher environment, the separation between target and sensor would have to be increased possibly two or three times to obtain the same degree of protection. An increase in sensor/target separation distance will always place additional constraints on the design of the system.

The requirement to score various types of projectiles with different rates of fire is another of the more difficult aspects of the problem. Because of the high rate-of-fire of the 7.62-mm machine gun (6,000 spm, 12,000 spm for dual guns), systems having lower rate-of-fire capability cannot be considered.

Lastly, the accuracy requirement itself is one of the most demanding. In order to score with 2 percent accuracy from 0 to 15 meters from target center, each round must be scored within ± 0.3 meter or roughly 1 foot. Vector information, while not strictly a requirement of the study, would greatly add to the complexity of both sensing and display, especially when required for multiple round scoring. Thus, the accuracy requirement appears to be a difficult one for much of the state-of-the-art scoring technology.

In summary, the problem is by no means a simple one, and it appeared even at the outset of the study that the "best approach" could possibly involve some degree of trade-off among the requirements of the SDR.

SECTION III

METHOD OF PROCEDURE

A. LITERATURE SEARCH

Imperative to any study is the gathering of as many facts as possible; therefore, a thorough literature survey was conducted on all available literature pertinent to the study; this included patents, government reports and periodicals. Literature was retrieved by means of the following key words: scoring, miss distance indicators, hit indicators, flight detection, gunshot detectors, firing error indicators, sensors and detectors, data transmission, display and projectile properties. The patents were covered from the year 1939 to 1967, and DOD's Technical Abstract Bulletin was searched from 1963 to 1969. The most useful literature came from the government reports. The journals which were available contained very little information in the areas of scoring and ballistics, however, support literature for transmission methods and acoustic theory was more plentiful.

After reviewing the literature survey of 287 articles with abstracts, some 110 reports were selected and ordered for the study. These are listed under REFERENCES, following Section VII, and in Appendix A, the Bibliography.

B. QUESTIONNAIRE

In addition to the literature survey, facts were to be gathered from a questionnaire which was sent to 45 scoring systems manufacturers, 55 component/subsystem manufacturers, and 27 user agencies. (The questionnaires are included as Appendix B.) Twenty questionnaires were returned, but only very few were satisfactorily completed. Many of the component/subsystem questionnaires were incomplete because the manufacturer believed that it would be too time-consuming. Several forwarded their catalogs instead of completing the questionnaire.

C. FIELD TRIPS

The final information input was primarily collected from trips taken to: (1) Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, for data on external and terminal ballistic parameters of gunship weapons, (2) Fort Rucker, Alabama and Fort Stewart, Georgia, for environmental data, human factors data and general scoring problems, and (3) to the Weather Bureau Agricultural Services Office, Auburn, Alabama for terrain data on potential water ranges. The water range concept is described in detail in Appendix [illegible].

D. CONSULTATIONS

In addition to the project staff, consultations were held with members of Sanders MITHRAS Division on problems pertaining to use of television and acoustic scoring methods. Consultations were also made with Winchester Division of Olin-Matheson Corporation regarding trajectory information, and with Bolta Products Division of General Tire Company regarding the use of polyethylene sheets for constructing simulated targets.

SECTION IV

RESULTS

A. SCORING METHODS

Table 1, at the end of this section, contains a listing of some 45 scoring systems. This information was located by means of the literature survey and survey letters directed to manufacturers and users of scoring systems. In many cases the information obtained was incomplete, but was found to be sufficient to rule out further investigation. Many of these systems were designed for air-to-air applications; however, they were included in the analysis as it was believed that they might have potential for air-to-ground applications. This same philosophy was applied to ground-to-ground and ground-to-air systems.

With regard to air-to-air scoring systems, it was found that practically all were designed for scoring single projectiles (rockets or missiles). Since the majority of the munitions specified in the SDR are fired in multiple round bursts, it was believed that this was sufficient justification for eliminating these as candidate systems. Exceptions are Motorola's Vector Scorer, Thiokol Chemical's TIMASS, and Sanders Associates' RASCORE M. The Vector Scorer system (monopulse radar) is still in the development stage, and as it has a maximum scoring limitation of 1200 spm, can not be considered at this time. If this system could be used in air-to-ground applications and the scoring limitation could be increased to 12,000 spm, further investigation would be warranted since it provides vectorial coverage in all three planes, and an accuracy of 5 percent at 30 meters.

Thiokol's TIMASS uses two microphones mounted on an aircraft target to obtain scoring information. The TIMASS system is interesting in that the required number of rounds which can be scored and the accuracy, approach that required by the SDR; however, it requires complex data reduction to obtain miss distance. The final evaluation test on this system has not been obtained, but it is believed that further investigation is not warranted due to its complexity and the fact that more appropriate acoustic systems are available already designed for air-to-ground applications.

The RASCORE M radar scorer, manufactured by Sanders Associates, is designed primarily for scoring missiles. It

does have an inherent capability to score up to 400 spm, however, the presently configured display indicator (miss-distance indicator) would have to be replaced with one or more miss-zone counters in order to meet the specified scoring requirements. For this reason and because the system would have to be located in the hazardous environment of the target, the RASCORE M system was not considered further for this application.

Of particular interest for the analysis were the air-to-ground scoring systems. Unfortunately, very little work has been done in this area and no systems not already known were uncovered by means of the literature survey. The two manufacturers of air-to-ground systems are Sanders Associates, Inc. and Del Mar Engineering. Sanders provides its RASCORE S system, a pulsed doppler radar, while Del Mar provides four acoustic scoring systems, each having somewhat different capabilities and applications. None of these systems provides vectorial coverage. Both basic types of systems approach or meet the accuracy and scoring rate requirements of the SDR. The Del Mar systems do provide miss distance information, but only in a maximum of five scoring zones when scoring rapid fire armament. Each system operates independent of target configuration; however, under certain conditions the operation of the acoustic systems are degraded by target shadowing. A detailed comparison of these systems is made in Section V.

B. TRANSMISSION METHODS

Regardless of the type of scoring sensor used, the data to be transmitted will relate to the number of rounds fired and will consist of a corresponding number of electrical pulses (from one pulse for individual rounds up to 12,000 ppm when maximum rate machine gun fire is used). For miss distance indication, several channels of this type of data may be required, each channel pertaining to the number of rounds falling in a particular miss-zone; i.e., 20 to 25 meters, 25 to 30 meters, etc. This type of information forms the basic requirement for any type of transmission method which will be used.

Transmission of data can be accomplished by two general methods; land lines or radio links. A trade-off between these two methods is given in Section V. The following paragraphs describe generally the various alternatives which may be used to transmit data using the two basic methods. A block diagram of the two methods of transmission is shown in Figure 1.

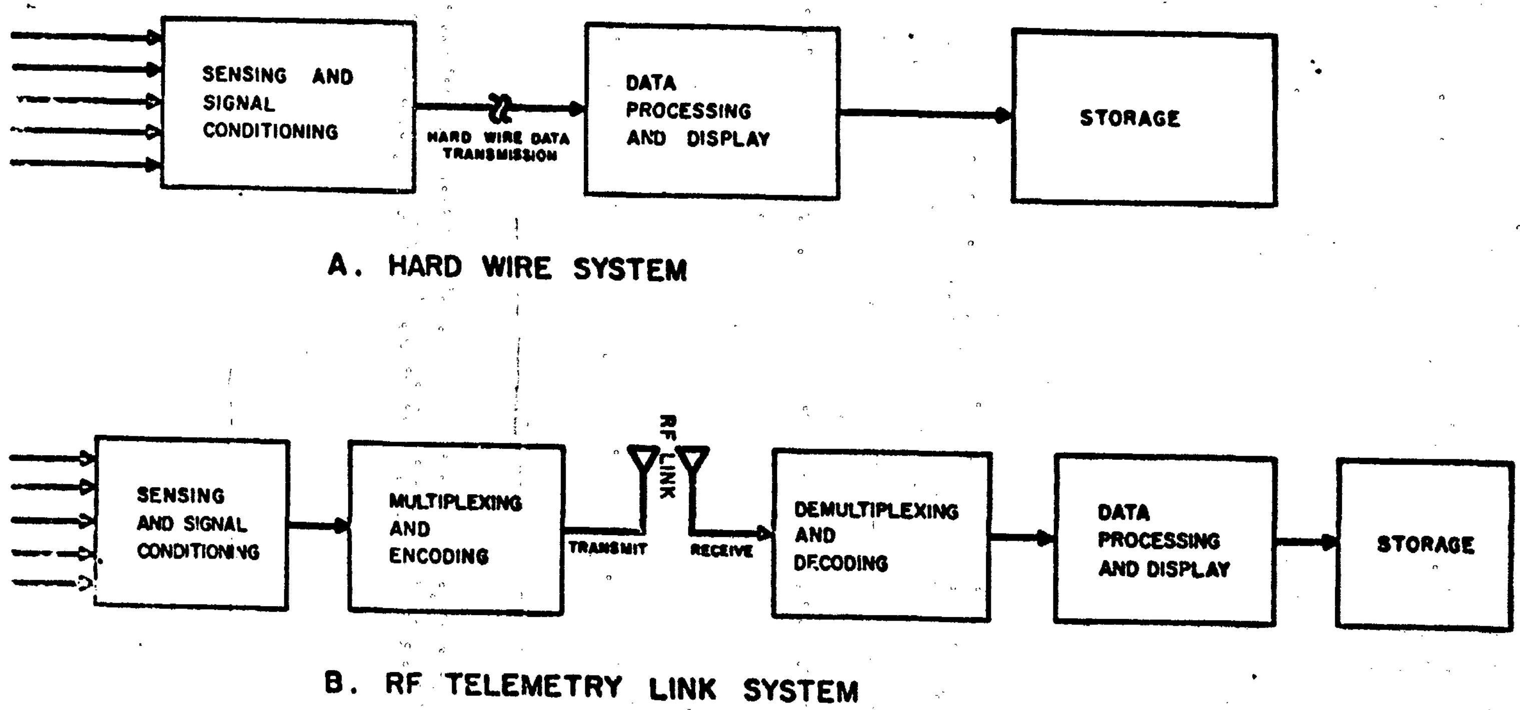

Figure 1. Block Diagram of Transmission Methods.

1. LAND LINES

Because of the hazardous environment found on firing ranges, any land lines used would have to be installed below ground. Depth of burial will be related to maximum crater depth and high explosive limits. (The interim scoring system in use at Fort Rucker is installed three feet deep; for maximum safety and reliability, a greater depth will probably be required.) Since scoring of up to six targets is required simultaneously, the main land line trench from the monitor area or control tower to some central point on the range would contain six cables or groups of cables if more than one per target is required. Either telephone pairs or coaxial cables could be used, however due to bandwidth limitations of telephone lines, it is expected that only coaxial cable will be used for this application. While there are types of coaxial cables which can be buried directly in the ground (impervious to moisture, mildew, etc.), the use of conduit would probably permit more rapid replacement of cables if required.

A third method of cable placement which was considered and which is discussed briefly in Section VI is walk-in maintenance tunnels. While the use of these large tunnels would be prohibitively expensive and unnecessary for cable burial alone, they would, if employed to facilitate maintenance and calibration, provide an ideal method of cabling sensing devices with a remote display.

The most significant disadvantage of land line transmission is its relatively fixed location of sensing devices. This problem could be resolved to some degree by providing several alternate cable terminals at each target site; however, no land line transmission method can be as portable as a radio link.

2. TELEMETRY

The RF frequency spectrum is a limited entity and considered to be a natural resource that must be conserved. Wasteful use of this spectrum by any system using electromagnetic radiation and reception can have adverse effects on military and civil activities. Consequently, high efficiency of the utilized spectrum and minimization of the susceptability to interference must be the goals for the systems (transmitter and receivers) which are manufactured and used for telemetry applications.

The standardized parameters and criteria for telemetry were devised by the Frequency Coordination Working Group of the Inter-Range Instrumentation Group (IRIG), with assistance from members of the Telemetry Working Group and the development groups of the three military services. The purpose of these parameters is to provide development and coordination agencies with design specifications on which to base equipment development and modification. Any telemetry equipment that may be used with scoring systems must not only be engineered to handle the necessary data and enviroment but must also adhere to the standards set up by IRIG which are outlined in document 106-66 Telemetry Standards.

The basic requirement for any type of telemetry transmission system will rely on the amount of information handled. In keeping with the idea of formulating a system concept for scoring with high reliability and accuracy, the volume of transmitted information must be reduced to an absolute minimum while still providing sufficient scoring capability. A block diagram of the RF transmission method is shown in its simplest form in Figure 1B.

The hardware necessary for use with an RF telemetry link, namely, transmitting, multiplexing, encoding and receiving, and de-multiplexing and decoding equipment has been used and proven for many years for the collection of various types of dynamic information. In standard applications telemetry equipment has displayed nominal MTBF of approximately 300 to 500 hours which is sufficient for the collection of short term data supported by experienced maintenance personnel.

Pulse modulation has long been used for data transmission because it is closely allied with time-division multiplexing, a technique that permits a number of separate data channels to share a single transmission medium by alloting a particular time interval to each channel. The channels are sampled in regular sequence and samples from the various channels are interleaved in time to form a single pulse train.

Many types of pulse modulation can be used. In pulse-amplitude modulation (PAM), for example, the height of an individual pulse represents the magnitude of the original signal at a given sampling instant. Pulse length represents the signal magnitude in pulse-duration modulation (PDM).

In both cases, the intelligence is carried in analog form. If the pulses were received exactly as transmitted, and if the receiving equipment accurately determined the appropriate characteristics of the received pulses, the original waveform could be reconstructed exactly. Because of noise and distortion, however, the received pulses are degraded versions of the transmitted pulses. As a pulse accumulates noise, its boundaries become uncertain, causing difficulty in reconstructing the received signal. Errors are cumulative and tend to get worse as the transmission distance increases.

Considerable immunity to noise and other transmission difficulties can be achieved if the multiplexed signal is coded as a series of identical pulses and spaces. Then the receiving equipment need only make a simple yes-or-no decision as to the presence or absence of a pulse at a particular time. This coded arrangement of binary pulses is the pulse-code-modulation (PCM) signal. Where the basic concept of PCM is relatively simple, the implementation of the theory to form an operating system can become somewhat more complex.

Whenever data is to be transmitted from one point to another, the question of whether to use an analog or a digital transmission system arises. Since FM is the most common analog technique used in telemetry, it most often provides the standard of comparison for pulse-code-modulation (PCM). No simple formula has been developed for comparing the two techniques because there are so many aspects to such a comparison. However, it is possible to compare them in general terms.

One of the most important points of comparison is the required accuracy of the system. If the data must be accurate to better than about 1 percent, PCM is usually the choice. If the requirements are very stringent, this is almost certain to be the deciding factor.

Where large numbers of channels are involved, PCM also has advantages, chiefly in size and weight. Also when lower power or a noisy transmission link results in a low signal-to-noise ratio PCM has the clear advantage. This comes about because the receiving equipment needs only to detect the presence or absence, not the height or shape,

of a pulse. Once the signal power is high enough so the decision level is clear of the noise, additional signal power merely increases the "safety margin" with little effect on the signal quality.

The fact that PCM is already in digital form lends itself well to digital data processing. Progressively higher quantities of data are being sought from smaller, faster, more reliable telemeters. Microcircuits now perform logic functions with high reliability. Here, PCM telemetry has had a definite advantage over FM systems because the development of analog microcircuits has lagged that of digital microcircuits.

Some of the major advantages that have been discussed briefly are what Sanders believes would be the necessary attributes for the telemetry equipment that might be used for high speed scoring systems. Since the need appears to be for large quantity, high speed data in this application, PCM is recommended for use should the decision to utilize telemetry be adopted in the final analysis.

C. ANALYSIS OF DISPLAY METHODS AND DEVICES

For scoring applications, the potential user requires a display device which will provide the numerical analog representing the number of projectiles falling on the target area. In general, display devices can be classified into three categories: (1) the mechanical types such as teletypewriters and plotters, (2) electronic types such as counters, and (3) light types such as a cathode ray tube or electroilluminesent panel. Because the mechanical types are speed limited and often display limited, the electronic and light type displays are the best solution for high speed information access. A militarized version of a CRT display is at most clumsy, bulky, and requires constant maintenance to ensure accuracy of the analog output. Electronic counters, on the other hand, provide a high speed numerical readout that is compact, lightweight, and inexpensive when compared to a CRT display. Such counters have reached a high degree of technical development and are highly reliable, therefore a device with these developed qualities appears to be the best choice for scoring system applications.

D. DESCRIPTION OF SENSING, TRANSMISSION, AND DISPLAY METHODS USED IN EXISTING AIR-TO-GROUND SYSTEMS

1. RASCORE S

a. Sensing and Processing

A 10-nanosecond radar pulse, reflected from a projectile heading towards a target, is mixed with a 9.7 GHz r-f frequency in the microwave subassembly to obtain a 10-nanosecond video pulse which is amplitude modulated by the doppler frequency of the scored projectile. This doppler frequency varies from 42 to 57.7 kHz in direct proportion to the radial velocity of the projectile with respect to the radar. False target information is rejected by a range gate which accepts only targets from 95 to 105 feet from the antenna. Signals from ricochets and debris are eliminated by the appropriate low cutoff doppler filters. The burst of doppler frequencies is envelope-detected and fed to the input of a threshold circuit; if the signal level satisfies the threshold requirement, a 3-millisecond scoring pulse is generated.

b. Transmission

The scoring pulse generated by the RASCORE S microwave subassembly is applied to a buried RG176A-U coaxial cable for transmission to the data presentation and recording assembly. As an alternative to the cable connection between the transmission and display points, a telemetry link may be used.

c. Display

The scoring pulse, corresponding to one round, advances the count of a four-digit electronic counter. At the end of an attack run, the operator presses a PRINT rocker switch and the number of the run, with the number of scored rounds, is printed on a paper tape by a digital recorder. The run number is also displayed on the control panel by a sequence counter. The paper tape automatically advances, the digital counter resets, and the sequence counter increases its count by one digit in preparation for scoring the next run. The display is visible in bright sunlight and at night.

2. DEL MAR SYSTEMS

a. Sensing and Processing

The various models of the Del Mar tactical air-to-ground scoring system are similar; Model DA-3/A is described below.

The pulse output of an acoustic transducer is connected, via a 300-foot cable, to a signal conditioning and transmission unit which converts it to a combination of analog (PDM) and digital elements. Each signal burst, containing the information pertaining to one round, starts with a synchronizing pulse, followed by zero to three binary-coded target identification pulses, and is completed by a data pulse whose duration is a function of calibrated signal amplitude. Maximum scoring time is 9.15 milliseconds per round. The miss distance is calibrated by a precision audio-frequency generator which simulates the electrical output of the acoustic transducer. Normal transducer outputs for given projectiles at given miss distances are known from the experimental firing of many rounds.

b. Transmission

A 200 to 240 MHz band carrier is frequency modulated by the data pulse with a maximum deviation of 500 kHz and transmitted from a disc-cone antenna with a minimum carrier power of 2 W. This signal is received by a similar antenna connected to a data reception and display unit located up to 5 miles away. The signal conditioning and transmission unit is powered by a 30V nickel-cadmium battery capable of 12 hours of continuous operation. Standby current is approximately 200 ma with peak current during data transmission being approximately 1.2 amps. The duty cycle depends on the number of rounds scored with the peak current existing for a maximum of 9.0 milliseconds per scored round.

c. Display

The data reception and display unit contains five counters, one for each of five zones. Each counter consists of three glow tubes to display a maximum count of 999 rounds per zone. The first zone counter scores hits from zero to 3 feet, the second, 3 to 6 feet, etc., to the fifth zone where scoring is from 12 to 15 feet. A scoring radius switch in the display unit converts the zone width from 3 to 50 feet. In the 50-foot position, the first counter scores from zero to 50 feet, the second counter, 50 to 100 feet, etc., to the fifth zone where scoring is from 200 to 250 feet.

A second switch in the display unit converts one of the counters into a presentation of miss distance in feet. In this mode, the system produces a pulse train for each round with each pulse corresponding to an incremental unit of distance. When the scoring radius switch is in the 3/15-foot position (3 feet per zone, 15-foot maximum radius), each pulse indicates 0.1 feet of the total miss distance for the round; at all other positions of the scoring radius switch each pulse indicates 1.0 foot of the total miss distance for the round.

The data reception and display unit requires approximately 60W of 115V, 60 Hz power.

The data reception and display unit requires approximately 60W of 115V, 60 Hz power.

Item No.	Designation	Manufacturer or User	Method Used	Type	Range	Accuracy
1.	800B	Babcock Co.	Pulsed radar	MDI	0-50 ft	±1ft
2.	800B-2	Babcock Co.	Pulsed radar	MDI	5-50 ft	±3 ft
3.	BIDOPS-P	Babcock Co.	Pulsed radar	MDI	0-50 ft 0-100 ft	±2½ ft ±4½ ft
4.	BIDOPS AN/APQ-35	Triad Corp.	CW radar	MDI	0-50 ft	±2½ ft
5.	AN/USQ-35	Babcock Co.	CW radar	MDI	0-50 ft	2½ ft
6.	CW Redemption Scorer	Dalmo Victor	Pulse radar	MDI	0-600 ft	±5
7.	SCOR-PAC	Daal Assoc. Inc.	Pulse radar	MDI	Unknown	Unknown
8.	AN/APQ-91	Dalmo Victor	Pulse radar	MDI	0-100 ft	±5 ft or 10% (Note)
9.	Esco Proximity Scorer	Electronic Spec. U. Shoe Co.	CW radar	Hit Indicator	0-15 ft	±15%
10.	Ratio Doppler Scorer	Keltec, Fla.	CW radar	MDI	0-250 ft	±5 ft or 10% (Note)
11.	Shipboard Video Doppler	NAFI	CW radar		More than 200 ft	Unknown
12.	MD-41	Nol Code 735 Corona, Cal.	CW radar	MDI	Less than 33 ft	Unknown
13.	Trans-Sonic MDI	Transonics	CW radar	Vector MDI	0-100 ft	±10% MD ±15% azimuth error
14.	TIMASS	Thiokol Chem.	Acoustical	MDI	0-10 ft	±5%
15.	Bullet MDI	Raven Elect.	Pulse radar	Vector MDI	0-100 ft	±5 ft MD ±3° azimuth and elevation error

NOTE: Whichever value is greater.

TABLE 1. NONCOOPERATIVE SCORING SYSTEMS (Cont'd)

	Accuracy	Rounds /Min.	Projective Velocity Limitations	Applications	Status	Projectile Scored	Reference
	±1ft	Unknown	Unknown	Air-Air	Active	105 mm shell	
	±3 ft	Unknown	Unknown	Air-Air	Active	Missiles	1
:	±2½ ft ±4½ ft	Unknown	Unknown	Air-Air Air-Ground	Active	Missiles	1,2,3
	±2½ ft	Unknown	Unknown	Air-Air	Active	Missiles & 105 mm	1,2,3
	2½ ft	Unknown	Unknown	Air-Air	Active	Missiles	1:
:	±5	Unknown	Unknown	Air-Air	Inactive	Missiles & 105 mm	1
	Unknown	Unknown	Unknown	Air-Air	Inactive	Missiles	1
:	±5 ft or 10% (Note)	Unknown	Unknown	Air-Air	Inactive	105 mm	
	±15%	Unknown	Unknown	Air-Air	Unknown	5 in. Rockets 105 mm missiles	
:	±5 ft or 10% (Note)	Unknown	Unknown	Air-Air	Active	Missiles	
in	Unknown	Unknown	Unknown	Air-Air	Active	Missiles	1
in	Unknown	Unknown	Unknown	Air-Air	Inactive	Missiles	1
:	±10% MD ±15% azimuth error	Unknown	Unknown	Air-Air	Inactive	Missiles	1
	±5%	6000	More than MACH 1	Air-Air	Active	Unknown	1
t	±5 ft MD ±3° azimuth and elevation error	Unknown	Unknown	Ground-Air	Dev. Stage	7.62 mm	

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Item No.	Designation	Manufacturer or User	Method Used	Type	Range	Accuracy
16.	Parpas	R. Parsons Babcock	Pulse Radar	MDI	20-50 ft	±5ft
17.	Tactical Air-Ground Remote Scorer	Del Mar Eng.	Acoustical	MDI	1.5-15 m 3.0-30 m	±5%
18.	Olle Bulow Model Lyth-22	Olle Bulow	Sonic	MDI	(See projectile scored	±5.6 ft
19.	Obscuration Scorer	Ford Instru.	Optical	MDI	0-100 ft	±5 ft
20.	Millimeter Scorer	Adv. Tech. Corp.	CW radar	MDI	0-100 fr	±5 ft or 5% (Note)
21.	Electro optical MD system	AF armament	Optical	MDI	0-30 m	±2.54 cm
22.	Radioplane Scorer	Radioplane Div. of Northrop	CW radar	MDI	0-100 ft	±5ft or 10%
23.	Charge Indep. Electrostatic Scorer	Librascope Div. Gen. Precision	Electro-Static	MDI	(See application)	±5ft or 10% (Note)
24.	Traid Vector MDI	Traid Corp.	Optical	Vector MDI	0-350 ft	±10%
25.	M.I.R.S.	NWC, China Lake	Optical V	Vector MDI	Unknown	±1% range ±0.5% aspect angle
26.	Supersonic FEI Camera Pods	NADC, Johnsville	Optical	Vector MDI	0-200 ft	±5%
27.	RASCORE M	Sanders Assoc.	Pulse radar	MDI	0-275 ft	±2.5 ft
28.	RASCORE S	Sanders Assoc.	Pulse radar	Hit Indicator	20 ft diam.	±1 ft
29.	AN/USQ-6(XN-Z)	Raytheon Mfg.	CW radar	MDI	0-100 ft	±10%

Note: Whichever value is greater

TABLE 1. NONCOOPERATIVE SCORING SYSTEM (Cont'd)

	Rounds	Projective Velocity Limitations	Applications	Status	Projectile Stored	Reference
	Unknown	Unknown	Air-Air	Active	5-in. Rockets	1
	6000	More than MACH 1	Air-Ground	Active	5.56-155 mm	1,4, Del Mar Eng. Co.
	Single /1500	More than MACH 1	Air-Air	Inactive	8 mm, range 0-15 ft 20mm, range 0-30 ft 40mm, range 0-40 ft 75 mm rocket, range 0-60 ft	1
	Unknown	Unknown	Air-Air	Inactive	105 mm	1,5
5%	Unknown	Unknown	Air-Air	Inactive	Unknown	1
	Unknown	Less than 2280 ft/sec	Air-Air	Lab Model only	Missiles	
10%	Unknown	Unknown	Air-Air	Inactive	Missiles	1
10%	Unknown	Unknown	Air, range 0-100 ft Ground-Air range, 0-100ft	Inactive	Missiles	
	Unknown	Unknown	Air-Air	Unknown	Missiles	1
e pect angle	Unknown	Unknown	Air-Air	Unknown	Missiles	1
	Unknown	Unknown	Air-Air	Unknown	Missiles	6,7,8
	500	Up to MACH 8	Ground-Air	Active	Missiles	1, Sanders Assoc. Inc.
	15,000	None	Air-Ground	Active	7.62 mm to 5 in.	9, Sanders Assoc. Inc.
	Unknown	Unknown	Air-Air	Inactive	5-in. rockets	1

2

Item No.	Designation	Manufacturer or User	Method Used	Type	Range	Accuracy	Rou /Mi
30.	Airborne Ground Fire Locator	Conductron Inc.	Acoustical	Ground Fire Locator	Unknown	Unknown	Unkn
31.	3C49C	Hydro Systems	Physical Contact	Hit indicator	Unknown	±2%	12,0
32.	3F43-1	Univ. Pittsburg	Infrared	Hit indicator	45-450	Unknown	Sing
33.	3F43-3A	Univ. Pittsburg	Infrared	Hit indicator	100-2000	Unknown	Sing
34.	DS-TAG-2-A	Dormier Syst. Ltd.	Pulse radar	Hit indicator	0-3.0-6. 0-9 m	±10%	Unkn
35.	L-B and MDI	Dewey Corp.	CW radar	MDI	0-50 ft	±7.6 ft	Unkn
36.	Vector Scorer	Motorola	Pulse radar	Vector MDI	0-100 0-200 ft	±5% ±10%	1200
37.	AN/DSQ-7	Babcock Elect.	Doppler radar	MDI	150 ft	±2 ft	Unkn
38.	DOFL Proximity Scorer	Diamond Ord. Fuse Labs.	Optical	Hit indicator	15 ft	±15%	Unkn
39.	Missile Scorer	Servo Corp.	CW radar	Hit indicator	Unknown	Unknown	Unkn
40.	Radar Scorer	Del Mar Eng.	CW radar	MDI	Unknown	Unknown	Unkn
41.	Strafing Scorer DA/3/C	Del Mar Eng.	Acoustical	MDI	3-250 ft	±5%	9000
42.	Strafing Scorer DA-3/E	Del Mar Eng.	Acoustical	MDI	0-18, 18-36 36-54m	±5%	6000
43.	Strafing Scorer DA-3/F	Del Mar Eng.	Acoustical	MDI	1,5-15m	±5%	9000
44.	Strafing Scorer DA-3/A	Del Mar Eng.	Acoustical	MDI	3-250 ft	±5%	6000
45.	Gunshot Detector	Melpar	Acoustical	MDI	0-100 ft	Unknown	Unkn

TABLE 1. NONCOOPERATIVE SCORING SYSTEMS (Cont'd)

[illegible]	Rounds /Min.	Projectile Velocity Limitations	Application	Status	Projectile Scored	Reference
[illegible]	Unknown	Unknown	Air-Air	Active	5-in. Rockets	1
	12,000	Unknown	Air-Ground	Unknown	30cal,50 cal, 20 mm	10
own	Single	Unknown	Ground-Ground		Unknown	11, 12
ow	Single	Unknown	Ground-Ground	Unknown	106 mm, 105 mm,	11
	Unknown	Unknown	Ground-Ground	Unknown	12.7-76 mm	13
ft	Unknown	Unknown	Ground-Ground	Unknown	105 mm	14, 15
	1200	MACH 7	Air-Air	Dev. Stage	105 mm & 1 sq.ft.	Motorola
:	Unknown	Unknown	Air-Air	Unknown	Missiles	2
	Unknown	Unknown	Air-Air	Inactive	Missiles	1
own	Unknown	Unknown	Air-Air	Unknown	Missiles	16
own	Unknown	Unknown	Air-Air	Inactive	Unknown	17
	9000	More than MACH 1	Air-Ground	Active	5.56-155 mm	Del Mar Eng.
	6000	More than MACH 1	Air-Ground	Active	5.56-155 mm	Del Mar Eng.
	9000	More than	Air-Ground	Active	5.56-155 mm	Del Mar Eng.
	6000	More than MACH 1	Air-Ground	Active	5.56-155 mm	Del Mar Eng.
own	Unknown	Unknown	Ground-Air	Inactive	Unknown	18

2

SECTION V

DISCUSSION

A. INTRODUCTION

This section presenta a trade-off analysis between the five systems determined by the results of the study to be most appropriate for application to the Armed Aircraft Qualification Range Scoring System. The systems are compared and analyzed in terms of their performance, economics, efficiency, reliability, and maintainability. Because the type of projectiles used has a broad impact on system criteria, a discussion on merits of live versus inert projectiles is presented at the beginning of the section.

B LIVE VERSUS INERT AMMUNITION

The type of ammunition to be used in this application is one of the most significant factors affecting the concept formulation. If live ammunition is used exclusively or even partially, target-mounted sensors or scoring systems must have a survival capability greater than field-qualified armored vehicles. For standoff scoring systems, or sensors, survival of the equipment also presents problems, but these can be overcome to a great extent by the use of protective bunkers and shielding. Regardless of the type of sensor used, maintenance of the scoring system and range involves safety considerations and is time consuming due to the presence of unexploded munitions. These must first be removed by EOD personnel before any work can be done to the scoring equipment or targets.

It would appear then, that the obvious choice would be to use inert ammunition at all helicopter gunnery ranges. However, several disadvantages result from the use of inert ammunition. The impact point of 40-mm grenades will not be visible to the student and instructor. This is also true of 2.75-inch rockets when impacting after engine burnout. Discussions with human factors people at Fort Rucker and officers representing the Department of Instruction at Fort Stewart indicate that this is objectionable for psychological reasons. Student motivation is decreased when detonation of the larger projectiles cannot be seen. This type of gunnery has been compared to Link trainer instruction rather than actual flight instruction.

A second disadvantage of the use of inert ammunition is that because the impact point of inert rounds cannot be seen, any rounds falling outside the scoring range are not scored and provide no information for corrective action. In a sense then,

these projectiles are wasted except for the negative information they provide in determining hit/miss percentages. Consequently, it is possible that more rounds will be required in order for the required proficiency to be attained: this of course would increase annual costs of ammunition expended in training.

The psychological and scoring problems associated with the use of inert projectiles must also be considered in terms of the relative importance of the various weapon systems in the overall training program. It appears that the larger types, rockets and grenades which can be equipped with either inert or live warheads, present the greatest training problem. Department of Instruction personnel at both Fort Rucker and Hunter/Stewart indicated that these larger weapons are the most difficult to learn to fire; the 40-mm because of its low velocity and subsequent high-arc trajectory; the 2.75-inch folding-fin rocket because of its susceptibility to relative wind and center-of-gravity shift during engine burn. In addition, the 2.75-inch rocket is dependent on helicopter trim and flight attitude, and both types are fired in short bursts which nominally contain one to three rounds. Clearly then, training considerations associated with these projectiles take precedence over the 7.62-mm ball ammunition which, because of tracer rounds and its high rate of fire, can be "walked" into the target with some ease since the target area is generally devoid of foliage.

The use of live versus inert ammunition was also investigated from cost, procurement, and logistics considerations. Inquiries were addressed to the following:

* Picatinny Arsenal
* Frankford Arsenal
* Olin Matheson Corporation
* U.S. Army Ammunition Supply Agency

Other than Fort Rucker, no useful information was obtained from these agencies. The information requested was either not available or classified. Fort Rucker, however, estimates that inert ammunition, when available has cost 2 percent more than live because of procurement problems. Although small compared to the total cost of training, this percentage would account for an annual cost increase of $96,000 per major facility at the current training rate.[1]

[1]Details given in Section VI, paragraph E.

As a result of the foregoing considerations, it is determined that the use of live ammunition, is the most appropriate course to pursue even though it presents problems in equipment survival and range maintenance. However, the requirements of the SDR have been weighted against the use of both types of ammunition, where applicable, to assure the best possible concept.

C. PERFORMANCE

The following is an evaluation of scoring systems, data links, and targets in terms of the performance standards set by the SDR.

1. SYSTEMS AND DATA LINKS

The characteristics of the five most suitable systems are summarized in Table 2. These five systems fall into two categories, four systems made by Del Mar Engineering, all dependent on an acoustic sensor located at the target and one system made by Sanders Associates, Inc., which projects a radar window in front of the target from an antenna facing, but remote from, the target.

a. Tactical Situations

Neither radar or acoustic systems can be easily adapted to different field tactical situations. A fairly permanent installation is required for the radar and for the hardwired acoustic system. The acoustic systems employing telemetry for data transmission offer somewhat more flexibility for relocation, but the cable between the acoustic transducer and electronics must be unearthed and reburied with each system relocation. For tactical situations involving approach of the gunship from different directions, the acoustic systems do offer an advantage in that they provide omnidirectional scoring.

b. Components

All systems provide a hit-count measurement and transmission device, and hit-count central display units; only the RASCORE S provides a hit count and register central display unit. Registration of scored rounds and run number is automatically printed on a paper tape when a rocker switch is pressed on the unit. Except for the Del Mar DA-3/E, none of the systems include targets; the DA-3/E has a hit-count panel target wired to register hits, an acoustic transducer is also included to score miss zones.

TABLE 2.

COMPARISON OF RADAR AND ACOUSTIC SYSTEMS

Characteristic	Sanders RASCORE S	Del Mar DA-3/A	Del Mar DA-3/C	Del Mar DA-3/E	Del Mar DA-3/F
Type	Radar	Acoustic	Acoustic	Acoustic	Acoustic
Radar Frequency Band	X (9.39 GHz)	---	---	---	---
Telemetry Format	(Note 1)	FM	FM	---	FM
Data Link	Hardwire	Telemetry	Telemetry	Hardwire	Telemetry
Telemetry Carrier Frequency	216-260 MHz	220-240 MHz	1710-1850 MHz	---	1710-1850 MHz
Carrier Frequency Deviation	---	500 kHz	500 kHz	---	500 kHz
Carrier Power	---	2 W	2 W	---	2 W
Quantity of Scoring Zones	One	Five	One	Three	One
Auxiliary Outputs	Data pulse train output on back of electronic counter	Miss distance output for single rounds	---	---	---
Max Rounds Scored/Minute	19,000	6,000	9,000 plu	6,000	9,000 plus

Note:

1. Coaxial data link is standard with this system.

TABLE 2. COMPARISON OF RADAR AND ACOUSTIC SYSTEMS (CONT'D)

Characteristic	Sanders RASCORE S	Del Mar DA-3/A	Del Mar DA-3/C	Del Mar DA-3/E	Del Mar DA-3/F
Projectile Sizes Scored	7.62 mm - 6-inch	5.56-155 mm	5.56-155 mm	5.56-70 mm	5.56-155 mm
Power Requirements	50 W, 115 V, 60 Hz	60 W, 115 V, 60 Hz, 30-V battery	60 W, 115 V, 60 Hz, 30-V battery	100 W, 115 V, 60 Hz	60 W, 115 V, 60 Hz, 30-V battery
Accuracy	The accuracy figure for all five systems is ±5 percent; e.g., if a system indicates 100 hits in a given zone, the actual count is not less than 95 or more than 105. When the DA-3/A is used to measure miss distance for single rounds, a reading of 100 feet at the display corresponds to an impact point not less than 95 feet, or more than 105 feet from the sensor.				
Reliability (MTBF)	1300 hours	(Note 2)	(Note 2)	(Note 2)	700 hours
Attack Angle Limits:	±30° from target normal	None	None	None	None
Data Format	Each round has 3-msec pulse.	Each round has: 1. Synch pulse 2. Binary coded target ID pulse and 3. PDM data pulse.	Same as DA-3/A	Same as DA-3/A	Same as DA-3/A

Note:

2. No MTBF computed but should be similar to value for Del Mar Model DA-3/F

TABLE 2. COMPARISON OF RADAR AND ACOUSTIC SYSTEMS (CONT'D)

Characteristic	Sanders RASCORE S	Del Mar DA-3/A	Del Mar DA-3/C	Del Mar DA-3/E	Del Mar DA-3/F
Range (Max Separation between Transmission and Display Units)	Exceeds requirements set by size of range	5 mi	5 mi	10,000 feet (more if required)	5 mi
Max Scoring Time/Round	3.00 msec	9.15 msec	6.15 msec	10.00 msec	6.15 msec
Maintenance:	(Note 3)	---	---	---	---
Calibration	Target simulator and field strength meter	Precision audio frequency generator	Same as DA-3/A	Same as DA-3/A	Same as DA-3/A
Battery Charging	---	Del Mar Battery Charger	Same as DA-3/A	---	Same as DA-3/A

Note:

3. RASCORE S includes built-in meter for measuring power supply voltage, magnetron power output, and mixer crystal current

c. Operational Limits

The hit-count measurement and transmission devices in all systems are capable of transmitting a signal to a display unit located off the largest range specified in the SDR; viz, 2,000 meters by 6,000 meters.

d. Environment

The five systems are all capable of day and night operation. The RASCORE S meets the requirements for operation under intermediate climatic conditions as defined in Change 1, AR705-15, except for the lower limit of ambient temperature. The requirement is for -25 degrees F, the equipment design is for 0 degrees F. Component changes can be made to meet these requirements. Del Mar Models DA-3/A, -3/C, and -3/F have not received formal environmental testing, but similar systems have passed all environmental requirements of NTDC-STD-115.[2]

e. Projectile Sizes Scored

The RASCORE S and Del Mar Models DA-3/A, -3/C, and -3/F score hit data for live projectiles in sizes exceeding the specified requirement of 7.62-mm to 6-inch. Of this group, only the -3/A provides scalar miss distance data and this information is limited to single rounds. The Del Mar DA-3/E has an upper size limit of 70 mm. None of the Del Mar systems will score inert 40-mm grenades; 2.75-inch rockets will only score if they impact at 1250 fps or more: the acoustic sensor can score subsonic projectiles only on their detonations. The RASCORE S can score both live and inert rounds equally well.

f. Scoring Rate

The systems are all capable of scoring a single machinegun or multiple machineguns with rates of fire up to 6000 spm on a single firing run. The Del Mar systems can score different sized projectiles on separate firing runs if an amplifier gain adjustment is made each time the projectile size is changed. The RASCORE S requires no adjustment to score different sizes.

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2. Letter to Sanders Associates, Inc., Bedford Division, Attention: Mr. Barry Lloyd, from O. B. Lolmaugh, Del Mar Engineering Laboratories, dated 17 June 1969, File No. [illegible]. Enclosures 1, 2, and 4: paragraph D4

g. Mixed Size Capability

The RASCORE S can score mixed rounds in the same firing run. Because the Del Mar systems require an amplifier gain adjustment for each size projectile scored, they cannot score mixed rounds in the same firing run.

h. Accuracy and Information Display

Only detonating projectiles (40-mm grenades and 2.75-inch rockets) scored by an acoustic sensor are counted in their terminal positions. Supersonic projectiles scored by acoustic sensors, and all projectiles scored by radar, are counted just before they impact. None of the five systems can deliver vector scoring data as desired by the SDR. The Del Mar DA-3/A can be set to read miss distances in feet for single rounds at a maximum distance of 999 feet in 1-foot increments. An optional setting produces a maximum reading of 99.9 feet in 0.1-foot increments. This greatly exceeds the minimum miss distance requirement of 30 meters specified. Since the overall advertised accuracy of the DA-3/A is 95 percent, and the SDR error limit is ±2 percent from 0 to 15 meters, and ±10 percent from 15 to 30 meters, the system accuracy does not fully meet the SDR requirement for distances under 15 meters. For rapid fire, the zone scoring mode of the DA-3/A is used as explained in detail in Section IV. The other four systems score in zones at all times. Like the DA-3/A, the other Del Mar systems have an overall error of ±5 percent (95 percent accuracy) and cannot meet the SDR requirement for distances up to 15 meters. The accuracy of the existing RASCORE S is 95 percent; system modifications under consideration for the AAQRSS are not expected to affect this figure significantly. The RASCORE S yields a single zone score count like the Del Mar Models DA-3/C and DA-3/F. Unlike any of the Del Mar models, the RASCORE S produces a run number and makes a permanent record of the score and run number on paper tape.

i. Multiple Target Display

The data format of the Del Mar systems includes a target identification pulse for each round scored to enable a single display to selectively accept signals from one of eight adjacent target site subsystems. Four r-f carrier frequencies are available as options with the Del Mar telemetering

links to provide isolation for a total of 32 adjacent targets. This applies to the Del Mar systems which employ telemetry as a standard data link; viz, DA-3/A, -3/C, and -3/F. The DA-3/E and the RASCORE S employ hardwired data links, an arrangement which eliminates interference between two adjacent systems. The RASCORE S could use a single cable to carry scoring data from six targets through one coaxial cable to one central display. As a development option, a telemetry link could be employed in place of hardwire to transmit the RASCORE S data. In their present state, all systems require one display per target.

j. Night Operation

All systems have a self-contained lighting capability for effective night operations.

k. Terrain and Exposure

All five systems are adaptable to desert, mountain, and jungle terrain. If the system components are covered with waterproof shrouds during periods of inactivity, no problem is anticipated in exposing them to the local climate for periods of up to 30 days.

l. Power Sources

The display units of all systems operate on the 115V, 60 Hz power available from standard Army generators. The RASCORE S and the DA-3/E operate entirely from 115V, 60 Hz power; the other three Del Mar systems require 30V rechargeable batteries for their transmission units.

m. Future Development

The 360-degree attack angle capability of the Del Mar acoustic sensors offers a possible advantage over the RASCORE S for future development. If the advanced Aerial Fire Support System is realized, there may be a need for a scorer that can count hits from rounds fired at the front and back of a target. The RASCORE S does not have this capability; a second system would be required to monitor the other side of the target.

2. TARGETS

Three types of targets representative of armored vehicles are available; these are: vehicular shells in current use, two-dimensional silhouette targets with hit detection devices, and three-dimensional targets constructed of a lightweight frame and outer skin. The vehicular shells in current use are old tanks or armored personnel carriers. At Hunter, some of these shells have acoustic sensors on top of the target; at Fort Rucker, the acoustic

sensors are located remote from the vehicular targets and are marked with a white "patch" at the top of a pylon. The most severe disadvantage for vehicle shell targets is that a path to the target area must be cleared of unexploded projectiles before the old target may be towed off and a new one is pulled in to replace it. This deficiency would not apply on a range restricted to the use of inert ammunition. Though they become damaged and loose some of their realistic appearance, the shell targets are cheap and durable; an occasional painting renews the targets, postponing the need for replacement.

Two-dimensional targets fail to provide realism if the helicopter attack angle becomes too steep, but their main problem is limited durability and the need for frequent replacement. They can withstand ball ammunition hits, but will be destroyed by a direct hit from a live warhead. The best application for two-dimensional targets is probably to simulate personnel. To eliminate the need for frequency replacement, these targets can possibly be limited to strafing with 7.62-mm projectiles. Each target can consist of a human sized silhouette cut from sheet polyethylene and mounted on a concrete base. For use with an acoustic system, a number of these targets can be randomly arranged within the confines of a circle with an acoustic sensor at its center; the sensor can then score all rounds entering the circle. The radius of this circle can vary widely depending on the model of acoustic system selected. If desired, a projectile can be scored as far as 250 feet from the sensor.

In its present form, the RASCORE S illuminates a circular radar window 20 feet in diameter at a distance of 100 ± 5 feet from the antenna sensor. The planned modification for the AAQRSS application would illuminate an elliptical window with a vertical minor axis of 8 and a horizontal major axis of 30 feet at a distance of 300 ± 5 feet from the antenna. With this window, targets can be arranged randomly within an area behind the window. The confines of this area would be 30 feet wide (15 feet on either side of the boresight of the radar beam) by 7 feet deep. All projectiles entering this area would be scored.

Lightweight three-dimensional targets made of polyethylene provide realism at all angles and can be replaced from above with helicopters. Like the two-dimensional targets, their weakness is limited durability and the expense and complexity of frequency replacement. (See paragraph G in this section for details.) They can withstand almost unlimited ball ammunition hits, but will be destroyed by a direct hit from a live warhead.

D. ECONOMICS

1. SYSTEMS

The estimated non-production cost of the RASCORE S system and the most expensive acoustic system, the Del Mar DA-3/A are comparative; other acoustic systems are priced lower depending on capability with the model DA-3/F being somewhat less than half of the cost of the RASCORE S system. Although the Model DA-3/A is high in comparison to the other acoustic systems, it does provide more scoring data; this includes scalar miss distances for single rounds, and five-zone scoring for rapid fire.

2. DATA LINKS

Telemetry links, which are standard with all Del Mar systems except the Model DA-3/A, offer more flexibility than hardwired systems, but are poor from the economic standpoint because of their potentially low reliability and high maintenance costs. A telemetered system is not tied to a cable on the display side and may be moved to follow a target with little difficulty. This is a considerable advantage for a range where targets are very small, lightweight, and often moved; it is little or no advantage on a gunship range where target sites are potentially fixed. (See paragraph G.2. in this section.) The principal cost determinants in this extremely severe environment are reliability and maintainability. The Del Mar telemetering systems all require a transmitter, receiver, and two disc-cone antennas. Even under the best conditions, these extra components decrease reliability by adding to the length and complexity of the system chain. Since the transmitter and its associated antenna will be exposed to the gunfire of the range, the chance of damage is greatly increased. The transmitting antenna must be above the ground, and will be difficult to protect. Replacing damaged components will be costly and time consuming.

The estimated cost for a telemetry link for use with the RASCORE S is $5,000.00; this includes the cost of a battery supply for the range located end of the equipment.[3] The estimated cost of running three cables at a depth of 4.0 feet is $00.6976 per foot. This figure includes the cost of cable and trench; the breakdown is as follows:

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[3]Sanders Associates, Bedford Division.

- Cost of control cable per foot $.0186[4]
- Cost of power cable per foot .0900[5]
- Cost of coaxial data cable per foot .1155[6]
- Cost of digging trench per foot .4735[7]
- Total cost of cable and installation per foot .6976 = $.70

Figure 2 shows a typical range layout consisting of six targets; the RASCORE S is taken as an example. Bunker protected standoff sensors and receiver/transmitters are cabled to a display point at one corner of the range. The cable length between the display point and one of the centrally located targets, equal to 4,550 meters (14,929 feet), is the average length of a data link. Since this is the largest range specified by the SDR, the length and cost of the average data links on most ranges would be lower. Assuming a data link of 14,929 feet and a total cable and installation price of $.70/foot, the cost is approximately $10,450.00. The cost of data links serving additional targets would have a lower cost per foot than that of the first target because one trench could be used for most of the cable run.

3. TARGETS

A price check was made to determine potential target costs. Del Mar makes a lightweight three-dimensional target which can be replaced from the air, but its unit cost is high, approximately $900.00 each in quantities of four. Bolta Products Division of the General Tire Company, Lawrence,

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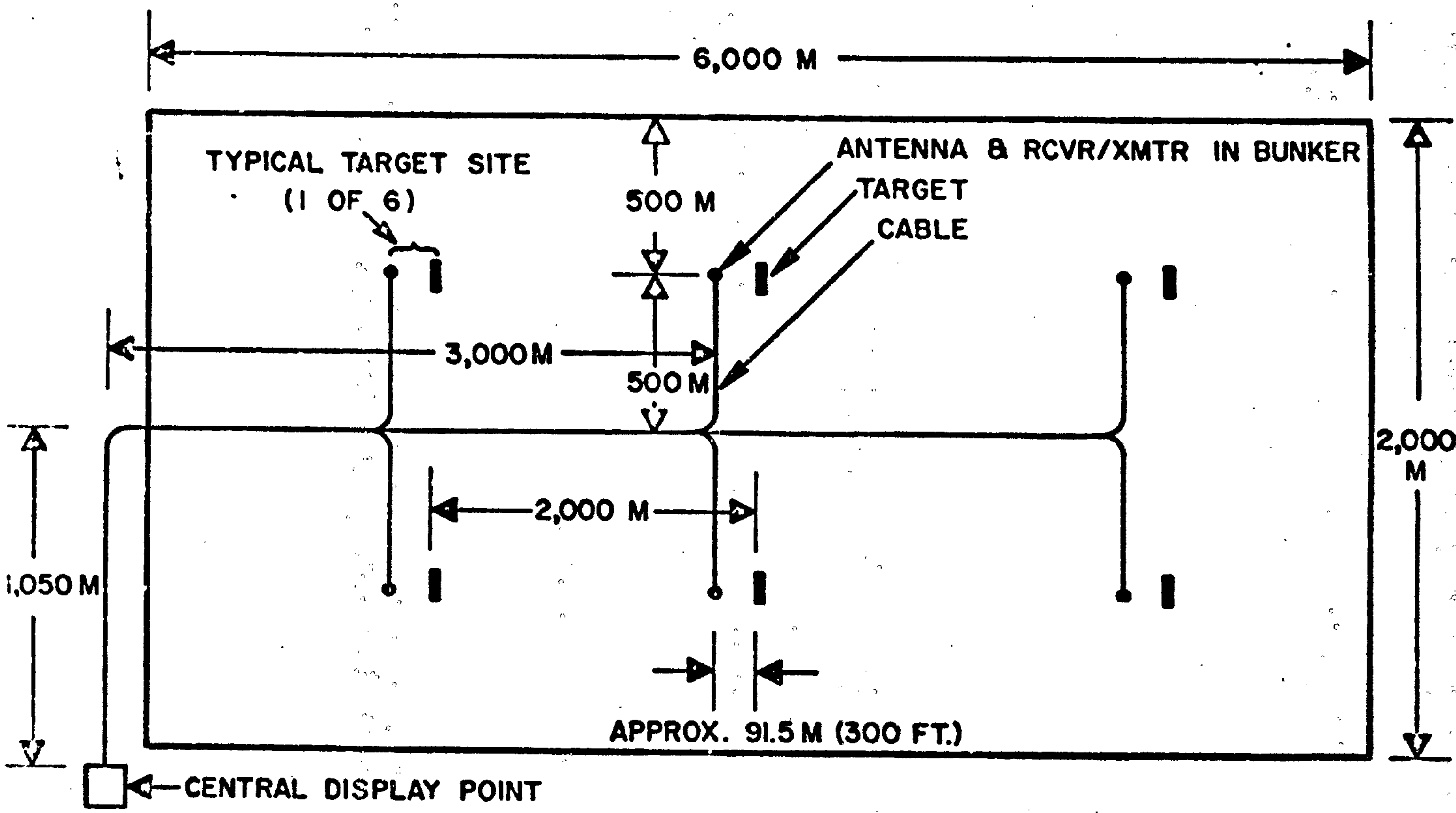
4. The Radio Electronic Master, Trade No. 8443, p. 1654 (Reference 19)

5. The Radio Electronic Master, Trade No. 8477, p. 1654 (Reference 19)

6. The Radio Electronic Master, Trade No. 4488, p. 1713 (Reference 19)

7. Sanders Associates, Bedford Division (rate per foot can easily vary by a factor of two or more depending upon terrain type).



Note: This diagram shows one possible arrangement of targets and sensors. Other arrangements, including additional targets sites could be employed.

Figure 2. Typical Range Layout.

Massachusetts was also contacted regarding the cost of polyethylene sheet stock of the same formulation used in silhouette targets for a prior NTDC contract. Estimates obtained indicate that an M47 tank target can be manufactured in production quantities for less than $[illegible]00.00 per target.

The worn-out bodies of armored personnel carriers and other armored vehicles are the cheapest form of target available. When the vehicle is stripped for parts and dragged onto the range, it has only scrap value, but its durable structure assures a longer target life than any of the other types under consideration. The only maintenance cost of the vehicular shell target once it is installed, is the price of an optional monthly painting to keep the target visible and realistic.

E. TRAINER EFFICIENCY

Since no vector information is provided by any of the electronic systems, the pilot instructor's evaluation is a valuable and necessary supplement to the information supplied by the electronic scorer. The scorer presents an accurate score for the objective comparison of student performance; the pilot instructor will provide the long, short, left or right information required by the student to help him bring his shot grouping to the target center. This approach, though not as desirable as a vector electronic scoring system, is potentially much more accurate than any score the instructor pilot could deliver alone. Consider the following variables affecting the instructor pilot's scoring during a burst of machine gun fire:

(1) Dust stirred up by the initial projectiles obscuring the face of the target;

(2) Innate differences in scoring ability among various instructors;

(3) Environmental conditions influencing visability such as precipitation, haze, and night conditions;

(4) Attitude of the instructor toward the student; and

(5) Guesswork on the part of the instructor pilot because he cannot see the bullet holes in the target.

An electronic scoring system would be immune to all of these variables; it offers an accurate, quantitative, and objective replacement for instructor scoring.

Though instructor pilot scoring is not accurate, it is reliable; if any form of electronic scoring is to replace the instructor pilot, it must be reliable or it is no improvement. The subject of reliability is discussed in detail below.

F. RELIABILITY

Besides the discussion contained here, more information on reliability, including factors influencing MTBF, is presented in Section VI.

1. SYSTEMS

On a trip to the helicopter gunship ranges at Hunter Army Air Base, Savannah, Georgia, and the U.S. Army Aviation School, Fort Rucker, Alabama, Sanders Associates found that the acoustic systems were not operating. The reason for this is the severe environment of the gunship range coupled with the location of the system sensor at the target. Any electronic equipment is certain to have a difficult existence under these conditions. Miss distances, scoring zones, and other distinctions that make one system appear a better choice than another are outweighed by the need for reliability. Electronic scoring is accurate (90 percent or better)[8], and the SDR states the "inflight observation" is inaccurate.[9] The problem with electronic scoring is reliability; if an electronic system can be made to approach instructor pilot reliability, it will be a great improvement over his scoring because it delivers a more accurate score than the instructor pilot.

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8. Department of the Air Force, Headquarters, USAF Tactical Fighter Weapons Center, Nellis Air Force Base, Nevada <u>TAC Test 66-4S, Electronic Target Scoring (Final Report),</u> 28 August 1967; paragraph 7(b) "The DA-3 System: .... Appeared to be capable of scoring strafe results with an accuracy of greater than 90%." (Reference 4)

   Sanders Associates, Inc., Bedford Division, Bedford, Massachusetts <u>A Synopsis of Operational Data Obtained During Field Tests of RASCORE S (Automatic Strafing Target System) 1 July 1968</u>; page 24 (Reference 9)

9. Department of the Army Approved Small Development Requirement (SDR) for an Armed Aircraft Qualification Range System paragraph [illegible]; "... inflight observation .... is inaccurate ...." (Reference [illegible])

The failure of the acoustic systems presently installed at Hunter and Fort Rucker suggests that they are not suitable in this application; the RASCORE S with its standoff sensor offers the prospect for a high reliability system. Because experience has shown that the area within approximately a 100 meters radius around a gunship range target is devastated, the existing design distance for the RASCORE S sensor will be changed from 100 to 300 feet for the AAQRSS application. Although this change does not move the sensor outside the area of devastation, it diminishes the chance of damage considerably. To reduce further the chance of damage to the antenna and receiver/transmitter assembly, they can be installed in a weatherproof bunker, and a radome can be mounted on the antenna assembly for protection against flying debris.

Unlike the radar antenna, which may be heavily shielded on three sides and from above, the acoustic sensor is difficult to protect. The acoustic sensor is omnidirectional and does its best job when there is no shielding to prevent data from reaching it. The current practice is to mount the sensor on top of the target, but this position is so exposed that the sensor's chance of survival is small, even when inert ammunition is being fired. A more protected arrangement was used during an evaluation of the Del Mar DA-3 Acoustiscore System at Nellis Air Force Base in Nevada. The transducer was mounted at the bottom of a two-dimensional strafing target between the target face and a pile of sand bags. During 13 sorties, consisting of three runs each, 20-mm projectiles were fired at the target; the following is a partial list of the difficulties experienced: the transducer was knocked down, reducing the size of its acoustical pattern; the transducer cable was severed, making the system inoperative; and the transducer was creased by a projectile and was not reliable for the remainder of the firing.[10] The acoustic sensor had two advantages during the strafing runs that it would not have had on the helicopter gunship range: the sensor was protected by sand bags, and

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10. Department of the Air Force, Headquarters, USAF Tactical Fighter Weapons Center, Nellis Air Force Base, Nevada <u>TAC Test 66-[illegible] Electronic Target Scoring (Final Report), 28 August 196[illegible]</u> paragraph 10. (Reference 4)

the 20-mm projectiles were not explosive. On the gunship range, the exposed mounting of the sensor and its cable increases the chance of damage to both. This is particularly true if live ammunition is used. If inert ammunition is used to improve sensor survival, 40-mm grenades will not score and 2.75-inch rockets will score only if they impact at 1250 fps or more.

2. DATA LINKS

Though it would add portability to a range system, it may be necessary to reject telemetry in the interest of reliability. The addition of a transmitter, receiver, and two antennas to a system whose worst potential problem is reliability may be sufficient reason for rejecting telemetry in favor of simpler, more reliable, hardwire. Since craters 3 feet deep are not uncommon on the range, the cables connecting the transmitting equipment to the data display must be buried at least 4 feet, preferably in conduit, for protection. A better solution would be to use walk-in maintenance tunnels for the cable, but this idea has been rejected as too expensive to implement.

G. MAINTAINABILITY

1. SYSTEMS AND DATA LINKS

a. Installation and Operation

None of the five systems can be installed with little or no site preparation. From the installation standpoint, the systems can be divided into two categories; Del Mar Models DA-3/A, DA-3/C, and DA-3/F are in one group, and RASCORE S and Del Mar Model DA-3/E are in the other. The first group employs an r-f data link; installation consists of mounting the sensor at the target, digging a protective trench for the 300-foot sensor cable, setting up the transmitting and display units with their tripod-mounted antennas in a line-of-sight with one another, and calibrating the system. The second group uses hardwired data and power cables buried in a trench between the transmission and display sites; the sensor of the DA-3/E must be mounted at the target and the sensor cable run to the transmission point in a trench. The antenna sensor of the RASCORE S would be mounted in a bunker at the transmission point, 300 feet in front of the target.

Though it is difficult to install, the RASCORE S system makes the range easy to operate because the radar has good potential reliability and consequent low maintenance requirements. All acoustic systems, except the DA-3/E with its hardwired data links, are easier to install than the RASCORE S, but have potentially low reliability because of their exposed sensors and complex r-f data links. The choice of acoustic systems will tend to make the range difficult to operate. The DA-3/E, like the RASCORE S, will be difficult to install, but somewhat more reliable than the other acoustic systems. On the other hand, its exposed acoustic sensor will tend to reduce its reliability, and, consequently, increase maintenance requirements.

b. Portability

The systems are not portable to any useful extent. Although the electronic components of all five scoring systems are transportable by medium helicopter sling load, the hardwired data links are not. The acoustic systems, with the exception of the DA-3/E which uses cable, emply r-f data links as standard, but their portability is still restricted by the 300-foot buried cables which tie each sensor to its associated transmitter.

c. Repair

Because of their modular construction, the systems present no special maintenance problems to personnel of Military Occupational Status (MOS) series 35B, Electronic Instrument Repairman.

To repair a system, the malfunction is first isolated to a major assembly, e.g., the receiver/transmitter assembly of the RASCORE S. The whole assembly is replaced to get the system back into operation as quickly as possible. The faulty assembly can then be taken to a repair shop off the range where the repairman can isolate the trouble to a specific module and replace it. The RASCORE S has been designed so that all repairs may be made at the direct support level or lower.

d. Calibration

The RASCORE S receiver/transmitter assembly has a built-in CALIBRATE switch and meter. Before the day's

operations begin, this switch is rotated to each of its positions and the meter is checked for a specified reading at each detent. To eliminate the need for flying maintenance personnel to the range for this purpose every day, an equipment modification is planned to sum the correct meter readings for a GO indication at the data presentation and recording assembly. If the GO indicator fails to illuminate, the malfunction can be isolated on the range by checking the built-in meter readings at the receiver/transmitter.

The acoustic systems have no built-in calibrating equipment; a battery powered test calibration unit is used to calibrate them. In addition, an amplifier gain setting must be made to calibrate the equipment for each type of round scored; the setting must be changed each time a different sized round is fired.

e. Storage and Transit

The five systems have not been formally tested for the storage and transit requirements of AR 705-15.

f. Batteries

In their present form, the RASCORE S and Del Mar Model DA-3/E receive 115-V, 60-Hz power from a point off the range; no battery power is required for either system. The signal conditioning and transmission units of Del Mar Models DA-3/A, -3/C, and -3/F each contain a 30-V nickel-cadmium battery capable of 12 hours of continuous operation. The battery provides all power for the range located elements of an acoustic system; this does not meet the SDR standard which requires 24 hours of operation between recharges. Replacing the discharged batteries with fresh ones is a hazardous and troublesome chore; it involves landing a man near the "dud" laden target site, another good reason for rejecting r-f data links.

g. Range Access

One solution to the hazard of maintaining equipment on a range where live ammunition is used is to build a boardwalk between the side of the range and the equipment sites. Maintenance personnel could be sure that undamaged portions of the walk contained no "duds". The presence of potentially live projectiles would be indicated by damaged boards.

2. TARGETS

The five scoring systems are not compatible with mobile target sites; once a target site is selected, it is permanent. Moving a site involves the following work in addition to moving the target itself. To move one of the acoustic systems the range must be cleared of unexploded projectiles, then, assuming that an r-f data link is used, the 300-foot sensor cable must be excavated and a new trench dug corresponding to the new target location. The RASCORE S presents a much larger problem if its target site is moved. After clearing the range, the antenna bunker serving the old site must be abandoned and a new one built, the antenna and receiver/transmitter assembly must be moved, and a trench must be dug from the old bunker to the new one so that the data and power cables may be extended. The Del Mar Model DA-3/E, which uses a hardwired data link, requires trenches for both the data link and the sensor cable.

Maintenance of vehicular shell targets is minimal once the target is in place. An occasional painting to preserve target realism is all that is necessary. Target life, which influences the amount of maintenance the target will require, will depend on the frequency of direct hits on the target, and the amount of distortion and diminished target visibility that can be tolerated without a loss of student motivation. Because of the durable nature of the vehicular shell target, it is certain to have a longer life than any other target type. When replacement is finally necessary, a road sized path must be cleared from the nearest range boundary to the target site. When all unexploded ammunition is removed, and the cleared path is marked, the remains of the old target shell may be dragged out and a new one pulled into place.

Two-dimensional personnel targets are light and easily transportable by helicopter. This type of target would only be feasible for use with 7.62-mm machinegun fire. The only problem with their replacement is installing and maintaining a marked circle for acoustically scored targets, or a marked rectangle for radar scored targets (paragraph C.2). This marker shows the area in which projectiles will be scored. One method of making the circular or rectangular marker permanent is to excavate the ground along the desired line, put a layer of sand in the trench, and then, using suitable forms and reinforcing material, pour concrete into the forms. The

top of the finished concrete marker should be painted a bright color to make it readily identifiable. The marker may require occasional repainting to keep it plainly visible. Replacing these targets is not potentially hazardous since there is no danage of unexploded projectiles with the 7.62-mm ammunition. The new targets can be flown in by helicopter and set up within the confines of the marker after the old targets are removed.

The lightweight three-dimensional M47 tank targets are helicopter transportable and can be replaced from the air; however, there are several problems which complicate the replacement. If an acoustic sensor is used, it is mounted on top of the target; this sensor must be lifted clear of the old frame before the frame can be lifted off the target site. When this is done, and a new target is lowered into place, the sensor must be replaced on the target. This is difficult to accomplish from the air. The RASCORE S has no sensor to remove and replace at the target; but there must be a positive way of orienting the target as it is lowered. Once positioned, the target must be held securely to prevent it from being moved by wind or explosive concussion. A steel or concrete framework permanently emplaced at the target site could possibly be used for this purpose. However, the mounting framework itself would be subject to periodic maintenance, especially if live rounds were used.

SECTION VI

CONCLUSIONS

A. INTRODUCTION

This section describes the best technical approach for an AAQRSS as selected by means of the trade-off analysis. An analysis of the performance and operating characteristics as well as a cost effectiveness of the selected system are also provided. Finally, the overall cost and schedule estimates for an installed system are submitted.

B. BEST TECHNICAL APPROACH

1. SCORING SYSTEMS

The RASCORE S radar scoring system is selected as the best approach for an AAQRSS in view of the requirements of the SDR and the other factors which must be considered. The existing design can be used with very little modification. Primary design effort would consist of providing a suitable radome for antenna protection and a protective bunker for the receiver/transmitter assembly. A minor modification in output power and a larger antenna would be required to achieve the required range separation (300 feet as opposed to the 100 feet for which the present RASCORE is designed). The magnetron currently used is operating at an attenuated power level so no change in critical components is required. Because of the requirement for realistic targets, the scoring window produced by the radar beam should be changed in shape from circular to oval to more closely coincide with the shape of a vehicle- or tank-type target, where applicable. This will require a change in antenna shape which is not considered a significant design effort.

As discussed in the preceding section, none of the scoring systems considered can supply vector information. Consequently, none can fully supplant the instructor pilot as a scoring device. The number of hits and/or the number of rounds falling into specific miss distance zones is valuable in evaluating student performance, but provides insufficient information for fully initiating corrective gunnery procedures. For this reason, it is mandatory that (1) the impact point of all rounds be visible -- necessitating the use of live ammunition, and (2) the instructor pilot provide direction of miss information; i.e., right, long, short and left, etc. Thus, the concept formulation inherently involves the augmentation of two scoring devices; the RASCORE to provide actual hit information, and the instructor pilot to supply direction-of-miss information.

The acoustic systems described in the preceding sections were the only possible candidate systems which could be considered for the AAQRSS. Their merits were considered carefully in selecting the best approach. The overriding factor in selecting the RASCORE system lies in the fact that all acoustic systems require target-mounted sensors. While the normal reliability of these systems is comparable to the RASCORE system, the overall reliability which must include survival in an environment deluged by live projectiles prohibits their use for this application. This decision was not made casually, but is based on two important considerations:

- Cost of replacement sensors
- Training time lost in range shut-down while range is being cleansed and sensors are being replaced

While these factors are, in themselves, not insignificant for individual sensor failure, the full implications cannot be understood until the frequency of individual sensor failure is considered. Based on information supplied by Fort Rucker training personnel[1], existing targets suffer six direct hits per day with 2.75-inch rockets and 12 direct hits per day with 40-mm grenades. This, of course, does not include shrapnel hits from these munitions when live rounds are used, nor does it include hits from 7.62-mm ball rounds.[2] Considering only that the direct hits cause sensor destruction, 18 sensors would require replacement each day if these ranges are fully instrumented with acoustic scoring systems.

The use of inert ammunition would greatly increase the survivability of target-mounted acoustic sensors, however the 40-mm grenades and subsonic rockets will not be scored. Because scoring of these projectiles is a primary requirement of the SDR, and because they are the most difficult to learn to fire, the use of inert ammunition in conjunction with acoustic scoring systems cannot be considered.

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1. Details given in paragraph D.4 in this section.

2. At Fort Rucker 740,000 rounds of 7.62-mm ammunition are fired per month at all targets on all ranges.

It is not suggested that the approach selected is absolutely immune to the survival problem and its attendant cost considerations; however, it is believed that the radar system when placed at 300 feet from the target and adequately shielded will provide accurate hit information on a reliable basis. The use of walk-in maintenance tunnels would further increase the survivability and maintainability to some extent, but it is believed that this increase would not be sufficient to justify the additional costs.

2. TRANSMISSION AND DISPLAY

For transmission of scoring data, buried coaxial cable is believed to be the best approach. A telemetry transmitter and antenna would be subject to damage or destruction from projectiles. Since the existing RASCORE S display unit is designed specifically to operate in conjunction with the receiver/transmitter unit, and because it represents the most suitable type of display (electronic counter), selection of a different type display was not considered. The tape printout provided with this display device will provide a history of hit information obtained during firing runs. This record will be of significant value both for evaluation of individual student performance and for evaluation of the effectiveness of the training program. A voice channel between display area and gunship will be required to provide near real time scoring information to the instructor pilot and student.

In selecting the method of transmission, all alternatives were considered. The use of an r-f link would permit the system to be portable in nature and make installation reliatively simple. This method does however, lower system reliability by introducing additional components into the system. Furthermore, adequate protection of the telemetry antenna poses an additional reliability problem. The combination r-f/hardwire link (as used in most Del Mar systems) retains the disadvantages of the r-f method without providing system portability. The hardwire method provides the most reliability, but has the disadvantages of being somewhat more expensive (initial cost) and of fixing the location of the system. In making the final selection, reliability was given precedence over cost and portability considerations; thus the hardwire method was chosen.

3. TARGETS

After considering the various advantages and disadvantages of the several types of targets which could be used as part of the AAQRSS, the tank or APC hulk targets currently used at helicopter gunnery ranges are selected as the best approach. These targets are greatly more durable than cloth or polyethylene simulated targets and are presumably supplied to the Army at little or no cost. Their only disadvantage lies in the difficulty or removing, replacing or redeploying them because of the necessity of cleansing the range. It is suggested that the useful life of this target can be extended by periodic repainting to aid in its visibility from gunships, and by the use of the lightest type of rocket warhead possible; i.e., those designed for use primarily against personnel.

Although two and three-dimensional cloth or polyethylene targets can be replaced quickly by air, eliminating the need for cleansing the range and the resultant range shut-down, the estimated frequency of replacement with its attendant cost makes them unfeasible for this application. The SDR also specifies the use of targets which realistically represent personnel and crew-served ground weapons. Such targets could be simulated using polyethylene; however, the same annual cost and deployment problems associated with the simulated vehicle targets would exist. This target would be feasible if only 7.62-mm ball ammunition were used, a condition not permitted by the SDR. If a special range were provided for 7.62-mm ammunition only, such targets would be feasible and would undoubtedly provide psychological advantages in training the students.

4. PROTECTIVE BUNKER AND RADOME

Both a protective bunker and radome will be required to insure the survival of the scoring system. It is recommended that this enclosure be constructed from reinforced concrete with 1/4-inch armor plate on top and rear (facing direction of fire) to assure long-term survival. An access door and an opening for the radar antenna will be required on the side facing the target. The use of an Armor-Ply door[3] which is faced with 1-inch steel should provide adequate protection from shrapnel hits. Protection for the antenna can be had by

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3. Product of U. S. Plywood Corporation

the use of low-loss sandwich radome material attached to the periphery of the antenna. The base of the bunker will be constructed using a 12-inch concrete slab mounted on four 24-inch concrete pilings. Three 3/8-24 stud bolts embedded in the concrete base in a triangular pattern are required for securing the antenna. Four 3/8-24 stud bolts should also be embedded in the base for securing the transmitter/receiver package. Approximate dimensions of the bunker are shown in Figure 3.

C. ANALYSIS OF SYSTEM PERFORMANCE AND OPERATING CHARACTERISTICS

1. ANGLE OF ENTRY LIMITATIONS

There are limitations on the angle of entry of projectiles into the target area by virtue of the safety restrictions of the firing ranges. It is expected that this condition will continue to be the procedure in the future. Even increasing the range sizes from 400 meters x 2500 meters to 2000 meters x 6000 meters as suggested by the SDR will not in itself relieve the helicopter gunships of the requirement to fire in selected directions. This is required because all fire must land in the range and because safety personnel must be protected from ricocheting projectiles. If the range area were increased to a size where the direction of fire could be unlimited, then the necessary monitoring and safety restraints could not be effectively and adequately carried out. This situation would be prohibitive in the more highly populated areas where the firing ranges are located. In this regard it is realistic and economical to select a sensing device which can score a large variety of small projectiles fired from a limited angle of entry. The angle of entry limitation for the RASCORE scoring system is 60 degrees; i.e., ± 30 degrees in any direction from the axis of the radar beam.

2. RELIABILITY AND MAINTAINABILITY ANALYSIS

a. General

The following discussion examines the requirements of the SDR and the AAQRSS study outline relating to reliability and maintainability and describes a system design

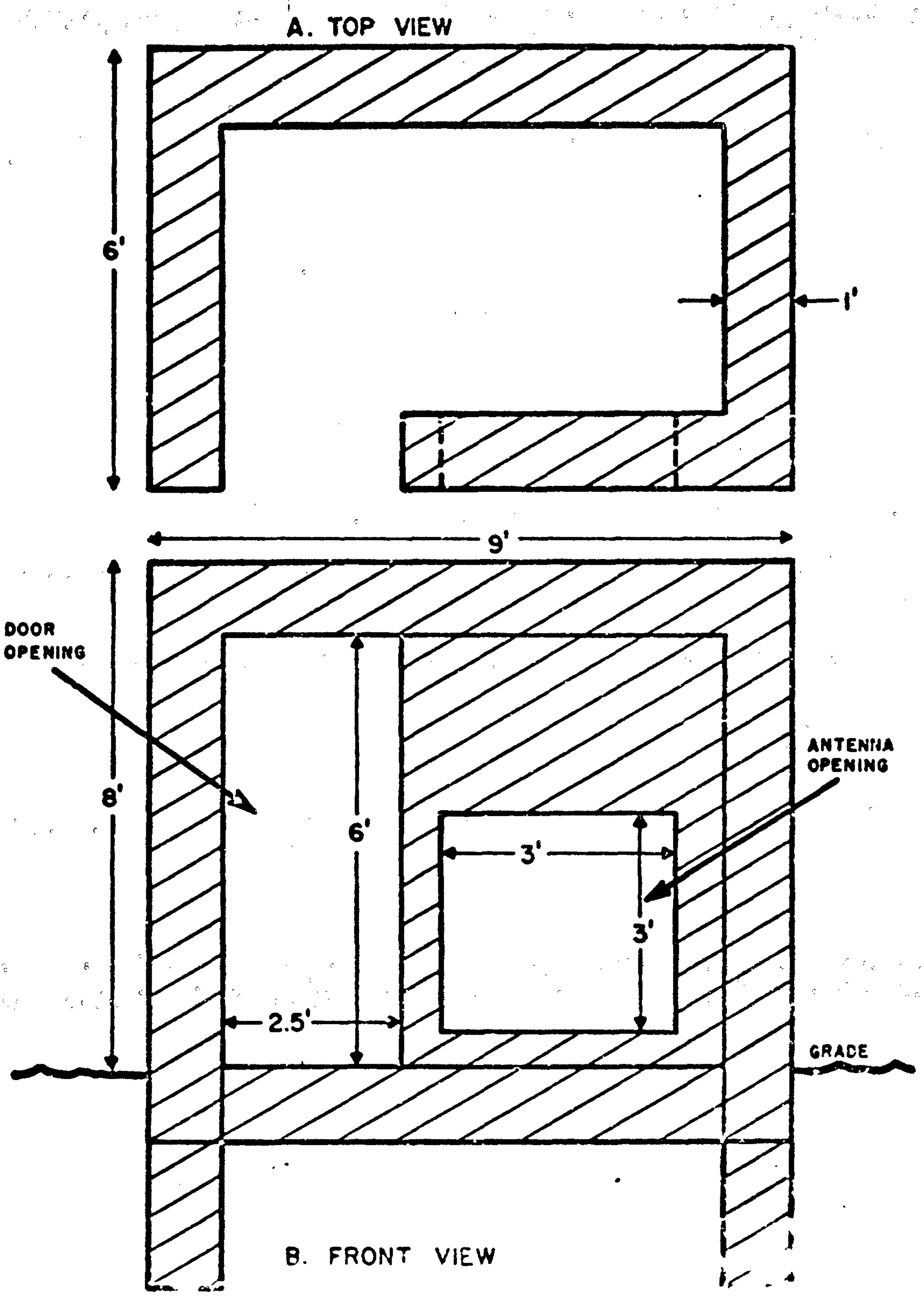

Figure 3. Radar Bun[illegible]

approach which will fulfill the requirements. In areas where the SDR is vague or inadequate, better requirements have been proposed together with the back-up data to justify the approach. The reliability and maintainability requirements are summarized below for reference:

(1) MIL-STD-785 Requirements for Reliability Program

(2) MIL-STD-470 Maintainability Program Requirements

(3) MIL-STD-471 Maintainability Demonstration

(4) AR 705-15 Operation of Material Under Extreme Conditions of Environment

(a) Intermediate Climatic Conditions (Operating)

- Thermal: 125 to -40 degrees F
- Humidity: 5 to 100 percent RH
- Rain: up to 0.45 inches/minute
- Snow: 20 pounds per square inch
- Icing: up to 2 inches of clear glaze
- Winds: 55 to 85 knot gusts
- Pressure: sea level to 8000 feet
- Snow and Dust Proof

(b) Transportation and Storage (Nonoperating)

- High Temperature: +155 degrees F for up to 4 hours/day
- Low Temperature: -65 degrees F for up to 12 hours/day
- Air Transit: to 40,000 feet

(5) Operational Requirements (from SDR)

(a) Score 6 targets/range (essential)

(b) Score 10 targets/range (desired)

(c) Simple installation (essential)

(d) Simple to repair and capable of individual component or module replacement (essential)

(e) Require one hour maintenance per 10 hours operation (essential)

(f) Require one hour maintenance per 20 hours operation (desired)

(g) Require no excessive calibration prior to operation (essential)

(h) Capable of prolonged periods of inactivity while exposed to the local environment climate (not to exceed 30 days), without requiring extensive preparation prior to activation (desired)

(i) Simple to establish, operate, and require a minimum of organizational maintenance (essential)

(j) Have a minimum acceptable mean time between failure of 20 hours under relatively heavy usage conditions (essential)

b. Discussion

The specifications MIL-STD-785, 470, and 471, are generally applied to military procurements. A program plan in reliability and maintainability should be prepared tailored to the program requirements. In general, selection of quality parts and ease of maintenance should be emphasized. A mathematical prediction should be performed, but it should not be refined extensively. A maintainability demonstration should be planned and performed. These requirements can be easily met by any contractor familiar with military procurements.

The environmental requirements from AR 705-15 (Ch. 1) are reasonable and can easily be met by quality military equipment. The equipment specification should call out specific environmental tests from MIL-STD-810 to cover the environments listed in AR 705-15. Several additional tests should be specified to cover anticipated environments such as acoustical noise (operating), transportation, vibration and shock (nonoperating), and bench handling (nonoperating).

The remainder of the requirements shown above are concerned with the system configuration and maintenance philosophy. The problem simply stated is to define a system which can score up to ten targets with an extremely high probability that six targets can be scored during a 20-hour operating period (training day).

The equipment defined for this discussion will be one or more independent parallel systems consisting of a stand-off radar sensor capable of scoring inert or live ammunition of various sizes and types and a remote data display.

c. Reliability Analysis

The overall quality which is desired for the target scoring equipment is high operational availability. It is essential that the equipment require not more than one hour of maintenance, including logistic time for every ten hours of operation. (Availability of 10/10+1 = .95).

It is desired that the maintenance be limited to one hour every twenty hours of operation. (Availability of 20/20+1 = .95). This desired requirement should be met since it is not beyond the capability of the system defined.

The requirement for a 20-hour MTBF for the system is too lenient. This is shown as follows:

where $R = e^{-\lambda t}$

R = reliability (probability of success)

t = mission time (20 hours)

λ = failure rate in failures/hour

The failure rate is:

$$\lambda = \frac{1}{MTBF} = \frac{1}{20} = .05 \text{ failures/hour}$$

Therefore:

$$R = e^{-.05 \times 20} = e^{-1} = .367$$

or in 100 days of operation, the system will fail on 63 days.

Assuming that 5 days failure is acceptable for 100 days operation.

$$R = e^{-\lambda t} = .95 = e^{-\lambda 20}$$

$$\lambda t = .0513$$

$$\lambda = \frac{.0513}{20} = .002565 \text{ failures/hour}$$

$$MTBF = \frac{1}{.002565} = 390 \text{ hours}$$

This number, 390 hours, is realistic for a system consisting of the modified RASCORE S sensor, a data transmission link and a data display, if the data is transmitted via land line. If an r-f data link is used with an MTBF of around 500 hours, which is realistic for an r-f data transmitter and receiver, it would constrain the sensor and data display to a combined MTBF of 1770 hours.

$$\lambda_{system} = .002565 = \lambda_{data\ link} + \lambda_{(sensor + display)}$$

$$\lambda_{(sensor + display)} = .002565 - .002 = .00565$$

$$MTBF = \frac{1}{.000565} = 1770 \text{ hours}$$

This would place an unduly harsh requirement on the sensor and data display. The calculated MTBF of the RASCORE S is 1306 hours.

Using an installation of up to ten systems, the probability of varying numbers of systems operating for 20 hours was calculated and is shown in Table 3. The table was calculated from the binomial distribution for completely independent systems, each of which has an MTBF of 390 hours.

d. Maintenance Concept

Since it is desired to use the target scoring system up to 20 hours per day with 1 hour of repair time, the mean time to repair should be specified as 1 hour. No contractor will assume liability for logistic time, since it is completely out of his control and cannot be designed into a product.

$$MTTR = \overline{M}_{CT} + \overline{M}_{PT} + \overline{M}_{LT}$$

MTTR = mean time to repair

$\overline{M}_{CT}$ = mean corrective maintenance time

$\overline{M}_{PT}$ = mean preventive maintenance time

$\overline{M}_{LT}$ = mean logistic time

Mean corrective and preventive maintenance time can be minimized by careful attention to good design practices such as:

- Modular construction
- Use of quick access captive hardware
- Built in test and self check features
- Long life high grade parts

TABLE 3. PROBABILITY OF SUCCESS FOR PARALLEL INDEPENDENT SCORING SYSTEMS

Number of Scoring Systems Installed (see note)	3	4	5	6	7
5	.9989	.9775	.7737		
6	.99990	.99776	.96722	.73509	
7	.99999	.99980	.99624	.95561	
8	.99997	.99996	.99961	.99420	.94275
9	.99997	.99997	.99994	.99934	.99163
10	.99999	.99999	.99999	.99993	.99896

Note: These calculations were made for a system consisting of a hit sensor and a remote display with a failure rate

λ = .002565 failures/hour.

Mean logistic time takes into account such factors as the time required to:

* Find the duty mechanic
* Collect tools and test equipment
* Locate the parts in stores
* Clear the range
* Drive to the site

Since a day consists of 24 hours and it is desired to use the range for 20 hours, it would be realistic to specify that the inherent MTTR ($\overline{M}_{CT} + \overline{M}_{PT}$) be 1 hour or less. This would leave 3 hours for logistic time. Every effort must be made to reduce logistic time. In addition, for further customer protection, the maximum inherent maintenance time $\overline{M}_{maxCT} + \overline{M}_{maxPT}$ should be specified as 2 hours. This places the requirement that 90 percent of all maintenance tasks (corrective and preventive) shall be accomplished in less than 2 hours. This will prevent a badly skewed distribution of maintenance times. These requirements should only apply to on-site maintenance.

The best approach to on-site maintenance is to limit tasks to check-out, alignment and replacement of major assemblies; i.e., packaged units. All troubleshooting and component replacement should be accomplished in an off-range maintenance shop where nonportable test equipment can be used.

The types of equipment which will be required for direct support maintenance are:

* High speed oscilloscope
* Multimeter
* Clip on milliammeter
* R-F power meter
* General purpose oscilloscope

Some component replacements could be carried out on site, but should not because of the time required.

The longest single element contributing to logistic maintenance time assuming operable spare black boxes are always kept on hand is the time required to cleanse the range. From a maintenance standpoint it would be advisable to interconnect the bunkers which house the sensors by hardened walk-in tunnels. There are three advantages to providing tunnels:

(1) Interconnecting power and data transmission wiring would be easily accessible when run in the tunnels.

(2) Personnel and wiring would be invulnerable to live ammunition even when the range was in use.

(3) It would be unnecessary to clear the range for maintenance personnel to work on equipment.

3. TRANSPORTABILITY

The typical RASCORE S system is shipped in three wooden crates, one each for the antenna, receiver/transmitter, and data presentation and recording assembly. The approximate dimensions of these crates are:

* Antenna -- 36 inches x 36 inches x 23 inches
* Receiver/Transmitter -- 14 inches x 22 inches x 22 inches
* Data presentation and recording assembly -- 21 inches x 27 inches x 22 inches

The system is easily transported by one man and no special handling methods are required.

4. POWER REQUIREMENTS

Power requirements for the system are 115 ±11.5 V, 60 ±3 Hz. The power consumption for the radar subsystem is 50 W while the data presentation and recording subsystem requires 100 W. Either commercial power or motor-generator power can be used as a power source.

5. LIMITATIONS ON HIT DETECTION RATE AND ACCURACY

The maximum scoring rate for the RASCORE system is 15,000 spm. Since the maximum firing rate will be 12,000 spm (two 7.62-mm machine guns firing simultaneously), all hits can be scored. If however, two rounds pass through the radar beam simultaneously, only one will be counted. For single projectiles of large size (6 inches), receiver saturation may occur. However, the duration of saturation would be of the order of microseconds which is of no consequence for individually fired projectiles. The accuracy limitation (12 inches) is independent of rate of fire and type of projectile.

6. PROJECTILE VELOCITY LIMITATIONS

The lower velocity limit for projectiles to be scored is 400 fps. This limit prevents flying debris, ricochet rounds, and shrapnel from being scored. No upper velocity limit exists.

7. ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS

The RASCORE S system has not been tested for electromagnetic interference characteristics in compliance with MIL-STD-461. However, tests and operation of the system on the firing ranges at Eglin Air Force Base have not indicated that the equipment is susceptible to, or causes, electromagnetic interference.

8. EFFECTS OF FLYING DEBRIS

A thick radome will be provided to protect the radar antenna from damage by flying debris, ricochet rounds, and shrapnel. In addition, a reinforced concrete bunker will be employed to prevent damage to the receiver/transmitter unit. The low velocity of debris, ricochet rounds, and shrapnel prevent them from causing erroneous scores.

9. PROBABILITY OF HIT NOT BEING DETECTED

The RASCORE S system was field tested at the Sanders Associates small arms test range in Bedford and at static and dynamic test ranges at Eglin Air Force Base. In all tests, results fully support, and sometimes exceed, the accuracy specification. Where the number of rounds fired differed from the number of rounds scored, evaluation of the targets showed that the unscored rounds passed through the edge of the scoring window; i.e., the 6-inch zone of uncertainty.

10. COMPLIANCE OF THE SYSTEM WITH SDR REQUIREMENTS

Table 4 lists the 22 requirements of the SDR and indicates where the best approach scoring system fails to meet individual requirements. Because some of the SDR requirements are interrelated, noncompliance must be shown in some cases more than once, for what is really one cause. Basically, the system fails to meet three general requirements:

TABLE 4. COMPLIANCE OF RASCORE BEST APPROACH WITH REQUIREMENTS OF SDR

Req. No.	Description	Complies	Fails to Comply	Discussion
a.	Targets used must realistically represent personnel, combat and tactical vehicles, and crew-served ground weapons appropriate to terrain and environment where installed.	X		
b.	System must be adaptable to simulation of various tactical situations.		X	Permanent installation required. All fire must be from one general direction.
c.	Targets, hit count measurement, transmission devices, and hit count and register central display must be included as part of system.	X		
d.	All components of range system must be portable in nature and easily assembled or disassembled.		X	Transmission system (hardwire) and bunker not easily assembled or disassembled. Equipment itself is portable and easily assembled and disassembled.
e.	The range system must be capable of operation through an area of 2,000 meters by 6,000 meters down to 400 meters by 2,500 meters.	X		
f.	Range system must be capable of day and night operations under intermediate climatic conditions as outlined in Change 1, AR 705-15. Kits will be provided if required for use in cold, hot-dry climates.	X		

TABLE 4. COMPLIANCE OF RASCORE BEST APPROACH WITH REQUIREMENTS OF SDR (CONT'D)

Req. No.	Description	Complies	Fails to Comply	Discussion
g.	The range system must acquire and record scoring (hit and near miss) data on the following armament subsystems: (1) 7.62-mm, (2) 50-cal, (3) 2.75 to 6-inch, (4) 40-mm, and (5) 20 and 30-mm.		X	Miss distance information not provided. All armament subsystems scored.
h.	System must be capable of scoring single or multiple machine guns with rates up to 6,000 spm on single firing run and combinations of those systems outlined in g (above) on consecutive, but separate firing runs.	X		
i.	System must be capable of recording the combinations of the different weapons outlined in g (above) in a single firing run.	X		
j.	System must be capable of recording the distances of the terminal projectile positions from the target centers up to miss distances of 30 meters. (See note.) MD recordings from 0 to 15 meters must be within ±2 percent and from 15 to 30 meters within ±10 percent. If no azimuth and elevation recordings are achieved hits must be scored for small targets and zone scoring will be used for all targets.		X	Scoring error for all rounds falling within radar "window" is ±5 percent. No miss distance information is provided. The instructor pilot will supply direction of miss information.

Note: Recording of azimuths and elevations desired if development time and cost not excessive.

TABLE 4. COMPLIANCE OF RASCORE BEST APPROACH WITH REQUIREMENTS OF SDR (CONT'D)

Req. No.	Description	Complies	Fails to Comply	Discussion
k.	Range system must be capable of collecting and recording data from each individual target and up to a minimum of six targets simultaneously.	X		
l.	Range system must be capable of collecting and recording data simultaneously from 10 targets.	X		
m.	Targets and associated instrumentation must:			
	(1) Be easy to install with little or no site preparation,		X	Bunkers are required at each site; underground cabling required between each radar installation and display site.
	(2) Be portable by medium helicopter sling load to facilitate rearrangement of target arrays,		X	Equipment is portable, but installation requirements prohibit rearrangement.
	(3) Be realistic in appearance,	X		
	(4) Be simple to repair and capable of individual component or module replacement,	X		
	(5) Require minimum maintenance as outlined in paragraph 4,	X		
	(6) Require no excessive calibration prior to operation, and	X		
	(7) Hit count and register central display unit must have a self contained lighting capability for night operation.			

TABLE 4. COMPLIANCE OF RASCORE BEST APPROACH WITH REQUIREMENTS OF SDR (CONT'D)

No.	Description	Complies	Fails to Comply	Discussion
n.	System must be capable of storage and transit under the conditions in AR 705-15 (i.e., army aircraft)	--	--	Not formally tested for compliance with storage and transit requirements.
o.	System must be adaptable to various types of terrain; i.e., desert, mountain, and jungle (see paragraph 1f).	X		
p.	System must be capable of prolonged periods of inactivity while exposed to the local environmental climate (not to exceed 30 days), without requiring extensive preparation prior to activation.	X		
q.	Command/control system must be adaptable to the electrical power available in CONUS or overseas, or be capable of operation utilizing standard US Army generators.	X		
r.	If batteries are used as power sources for target arrays, they must be capable of 24-hour operation prior to recharge.			Not applicable
s.	Range system must be simple to establish, operate, and require a minimum of organizational maintenance.	X		
t.	System must have an expansion capability so as to accommodate future developed aerial weapons and platforms; e.g., Advanced Aerial Fire Support System.		X	This system will not accommodate the 360-degree firing capability of the Cheyenne gunship.

TABLE 4. COMPLIANCE OF RASCORE BEST APPROACH WITH REQUIREMENTS OF SDR (CONT'D)

R. 1. No.	Description	Complies	Fails to Comply	Discussion
u.	Hit count and register central display unit should be capable of being mounted in the back of a standard US Army 3/4-ton vehicle or 3/4-ton trailer (1/4-ton truck or 1/4-ton trailer desired).	X		
v.	System will have a minimum acceptable mean time between failure of 20 hours under relatively heavy usage conditions.	X		System MTBF is 390 hours.

* No miss-distance information is available (requirements g and j)
* System requires site preparation which prohibits rearrangement (requirements b, d, m1, and m2)
* System must have an expansion capability so as to accommodate future developed aerial weapons and platforms; e.g., Advanced Aerial Fire Support System (requirement t).

Miss-distance information is not very useful unless direction-of-miss information is supplied with it to enable the gunner to get his shots on the target. To eliminate this deficiency in the selected system without paying high development costs for a vector system, the instructor pilot can call out the direction of miss from visual observation.

Because bunkers must be built and connecting cables buried as a part of site preparation, there is little chance of target rearrangement to simulate tactical situations. Since immobile hulk targets have been used successfully in the past without rearrangement, there seems little need to rearrange them in the future. The problem of the present range system is inaccurate scoring: the sacrifice of flexible target arrangements is justified as the price of an accurate and reliable scoring system.

The radar system lacks the expansion capability implicit in the Advanced Aerial Fire Support System. This requirement implies that the chosen system should be capable of scoring projectiles fired at the target from the back as well as the front. Since the radar system is limited to scoring unidirectional fire within 30 degrees of the boresight axis of the antenna, it cannot meet the requirement directly. There are two considerations which nullify this apparent failing of the radar system:

(1) Range safety makes two-directional fire all but prohibitive. See paragraph C1 in this section.

(2) Gunners can fire at a target as the gunship moves away from it without violating the unidirectional firing convention. The gunship must begin its run on the rear of the target without firing, after it passes over the target, firing in a direction opposite the flight path can commence.

Since the flight direction of the gunship is the only thing changed, no special scoring device or changed range layout is required. To facilitate air traffic flow over the range, one target can be reserved for fire from ships leaving the range, while other targets are used for approach firing in the conventional way.

D. COST EFFECTIVENESS OF PROPOSED SYSTEM

The cost effectiveness of the proposed system is a difficult quantity to define properly. For this reason it will be discussed with regard to four general areas. These are:

* Relationship to ultimate purpose of training
* Relationship to existing scoring methods
* Relationship to alternate scoring methods
* Relationship to existing and future use

1. RELATIONSHIP TO ULTIMATE PURPOSE OF TRAINING

Any improved training device or procedure that can lead to an increase in gunship crew proficiency should be considered on a cost effective basis even if percent of proficiency increase is small. To understand the validity of this statement, one must consider the mission of the gunship in combat situations. The gunship, because of its relatively slow speed and low attack altitude is an extremely vulnerable in attach situations. Jet fighters, which can be employed in similar missions, and which have some of the same armament, have a definite advantage in that their speed permits them to come closer to a target with a greater margin of safety in terms of possible return fire from the ground. The third cardinal rule for gunship employment is "Avoid flight in the deadman zone"[4] The deadman zone comprises those altitudes from 50 to 1000 feet with 50 to 500 feet being most hazardous.

4. FM 1-40, Attack Helicopter Gunnery, Volume 1 of 2. USAAS, Fort Rucker, Alabama; page 4-2 (reference 21)

The main defense against such hazardous conditions is described under cardinal rule 10. "Engage target at maximum effective range and disengage target before reaching enemy's effective antiaircraft range."[5] In order to comply with this rule and still accomplish the mission, a high level of gunship crew proficiency is required. Consequently, the training program, and accurate scoring to the extent that it affects the training program, are highly involved in the effectiveness of combat missions.

With regard to gunnery, costs enter the combat situation in two ways:

(1) Cost of missions where objectives were not met due to poor gunnery, and

(2) Cost of gunships and lives in terms of outright loss or casualties which might not have occurred if more accurate gunnery were employed.

The cost of ineffectual or lost missions is an impossible factor to estimate. This would involve losses of infantry personnel due to poor air support, forward area loss of positions to the enemy, and many other intangibles. Neglecting gunship crew casualties, one can, however, obtain some feel for cost effectiveness with regard to gunship losses. For example, if out of 100 gunship losses, 5 percent are lost due to inability to accomplish the mission at maximum (safe) ranges or due to inability to neutralize ground fire, a total of 5 gunships would have been lost. Using a nominal cost of $250,000 per gunship, this would result in a total cost of $1,250,000. It is not unrealistic to assume that more than 100 gunships have already been lost in the present conflict, nor is it unreal to assume that the 5 percent figure could be higher. Thus, improvement in scoring accuracy at gunship ranges could be highly cost effective in terms of the purpose of training.

5. FM 1-40, Attack Helicopter Gunnery, Volume 1 of 2. USAAS, Fort Rucker, Alabama; page 4-6 (reference 21)

2. RELATIONSHIP TO EXISTING SCORING METHOD

Because the present scoring method utilizes the instructor pilot as a scoring device, a cost-free method, no automatic scoring system can compete on a cost basis alone. However, in terms of effectiveness, both reliability and accuracy must be considered. It is believed that the instructor pilot is 100-percent reliable; however, it is conceivable that due to distractions that could occur during the firing run or even to occasional inattentiveness, this reliability is not always achieved. A reliability of 95 percent would be more credible, and this is comparable with that obtained by automatic scoring devices.

The accuracy of the instructor pilot is not known. Those in the best position to judge, the Army personnel in charge of training, estimate that this accuracy ranges from fair to poor depending upon the individual pilot and to some extent upon the environmental conditions present during the firing runs. From tests made by BRL[6] it is known that range estimation by pilots having in the order of 2,000 hours of helicopter experience is in error exceeding 25 percent over 70 percent of the tests made. In these tests, range errors of 50 percent were common and errors of 100 percent and above occurred occasionally. Thus, it can be concluded that human estimation of distance is, to say the least, imprecise. One would expect however, that pilot judgement of miss-distance would be better as the maximum distance involved is less and realistic targets would provide an improvement in visual reference. However, it is noteworthy that in the BRL tests conducted at slant ranges of 500 meters or less, errors of up to 100 percent were measured. While no absolute comparison can be made between instructor pilot accuracy and machine scoring, the BRL tests plus the opinion of training personnel would support a possible error of 25 percent in instructor scoring. As machine scoring in general, approaches accuracies of 95 percent, it would appear that it has a definite lead in effectiveness over instructor scoring.

6. Ballistic Research Laboratories, Technical Note No. 1683 A Study of the Air to Ground Range Estimation, Jan. 1968, page 3 (reference 22)

3. RELATIONSHIP TO ALTERNATE SCORING SYSTEMS

As has been previously discussed in this section, the major disadvantages of the acoustic scoring method is its vulnerability to destruction from projectiles. From a cost-effective standpoint, replacement cost of the sensor and connecting cable must be considered. However, the major disadvantage is in range down-time which must occur each time the system is disabled. During these periods, which will involve not only system maintenance but range cleansing as well, training must cease at the range involved. A system of this type is now installed at several of the training ranges and is not being used. The cost effectiveness of a nonfunctioning scoring system is not a subject requiring detailed analysis.

4. RELATIONSHIP TO PRESENT AND FUTURE USAGE[7]

a. Quantity of Students

At the present time 4,800 students per year are trained at Fort Rucker. Of these, 25 percent or 1,200 are given qualification training while 3,600 are given familiarization training only. It is expected that for fiscal year 1971, the total number of students will decrease to 4,400 with the same ratio of qualification to familiarization, however, there is a possibility that familiarization will be discontinued. Presently familiarization training includes only one hour in the range firing 3,000 rounds of 7.62 ammunition. Each student receiving qualification training spends 14 hours in the air over a two-week period.

b. Costs of Training

The amounts and estimated costs of ammunition expended per qualifying student at Fort Rucker are as follows:

Amount	Type	Cost/Round	Total Cost
7,400	7.62-mm	$00.105	$ 78
225	40-mm	$10.00	$2,250
31	2.75-inch	$55.00	$1,705
38	50-cal	$00.150	$ 6

Total cost per student is approximately $4,000. Annual cost of ammunition expended would be approximately $4,800,000.

7. Basic figures upon which this discussion is based were obtained from telephone conversation between D. Harriman (Sanders Associates, Inc.) and Department of Instruction personnel, Fort Rucker, Alabama.

Each qualification student spends 14 hours in the air. Hourly costs of helicopter are approximately $100. Thus annual helicopter costs are $1,680,000.

c. Estimated Hits on Targets

For rockets, 1 out of 20 score direct hits on targets and 1 out of 10 hit the target with shaprnel. For 40-mm grenades, 1 out of 8 score direct hits on the target and 1 out of 4 hit the target with shrapnel. For 100 students per month each firing 31 rockets. targets sustain 155 direct hits per month (6 per day) and 310 shrapnel hits per month (12 per day). In addition, targets sustain 320 direct hits from 40-mm grenades per month (12 per day) and 640 shrapnel hits (24 per day). Thus each day targets receive 18 direct hits from rockets or grenades and 36 shrapnel hits. If the three-dimensional tank targets are completely destroyed by a direct hit from one rocket or two grenades, annual replacement cost for targets is:

$$(155 + 160) \times 12 \times \$500 = \$1,890,000$$

This annual cost plus the cost of deploying these targets prohibits their use.

E. COST AND SCHEDULE ESTIMATE

1. RADAR SYSTEM

A budgetary cost was estimated for implementing the RASCORE S system into the AAQRSS. The estimate is based on costing data from a previous development contract plus the necessary cost for extending the range of the radar from 100 to 300 feet and subsequent testing of the system.

A breakdown of costs for one system is as follows.

a. Antenna assembly and Radome	$12,000
b. Receiver/Transmitter assembly	30,000
c. Display system assembly	7,000
Total system cost	$49,000

In production quantities the cost would be significantly lower. A rough budgetary estimate indicates that in quantities of 50 the antenna/radome assembly would cost $1,500 and the display system $5,000. The receiver/transmitter assembly price would accordingly drop to approximately $20,000 in quantities of 50.

The total system price would now be approximately $26,500.

A milestone chart for a single system and associated documentation is given in Table 5.

TABLE 5. MILESTONE CHART FOR ONE SYSTEM

Task	Months						
	1	2	3	4	5	6	7
System Delivery						∇	
Acceptance Demonstration					∇		
Test Documentation			∇				
Monthly Reports		∇	∇	∇	∇	∇	
Final Report							∇
O&M Manual (Draft)					∇		
O&M Manual (Final)							∇

2. SYSTEM IMPLEMENTATION

As discussed in Section V, the cost of a hardwired transmission link from a target area located in the center of the range to the central display point is estimated to be approximately $10,500. If more than one system were employed, the cost per system would decrease significantly as the main trench would be common to all systems. Because of the necessity for cleansing the range before implementing the transmission system, it is expected that the Army might provide the required trench. Since the cost of the trench represents approximately two-thirds of the transmission link, the cost of the transmission link per system would be reduced to approximately $3,500.

The cost of the protective bunker (Figure 3) required for each radar system is estimated to range between $1,000 and $3,000 depending on locality and whether union or non-union labor is used.

3. OPERATING COST ESTIMATES

Based on a daily operation of 20 hours and a 6-day week, a system will be operating 6240 hours per year. With a 320 hour MTBF, approximately 20 maintenance actions will be required per year. This will include failure such as printed circuit boards and miscellaneous items. Magnetron

life is estimated as a nominal 1000 hours, so scheduled magnetron replacement will be required approximately every 60 days. Because of the possibility of damage from shrapnel, it is estimated that the radome and antenna will require replacement occasionally. Estimated costs for component replacement are as follows:

Component	Cost	Frequency	Total Cost
Printed Circuit Boards	$150	20	$3,000
Magnetrons	900	6	5,400
Antenna/Radome Assembly	1500*	1.5	2,250
Total annual component replacement cost:			$10,650

*It is not expected that entire assembly will not require replacement more than once per year.

SECTION VII

RECOMMENDATIONS

This study has been directed at increasing the training efficiency of helicopter gunship crews through improvement of air-to-ground scoring techniques. The study was initiated with a survey and analysis of the present gunship scoring methods. Three general observations were made early in the study:

1. Instructor pilots are 100 percent reliable in providing a score but are generally inaccurate.

2. The firing ranges are available 100 percent of the time except for occasional range fires and target replacement.

3. Student motivation is markedly decreased when inert ammunition is used.

Data describing various types of existing and proposed scoring systems were evaluated. The results were compared with the requirements of the SDR. It was concluded that improved scoring methods can be implemented with the use of live ammunition. A minor increase in range maintenance requirements can be expected.

It is recommended that the Government procure an advanced development model of the electromagnetic system formulated as a result of this study. Test and evaluation of the model will confirm the results of the analysis and will establish the technical and economic basis for procurement of production systems.

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APPENDIX A

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APPENDIX B

QUESTIONNAIRE
AND
SURVEY LETTER

QUESTIONNAIRE

ARMED AIRCRAFT QUALIFICATION RANGE SCORING SYSTEM STUDY
FOR
NAVAL TRAINING DEVICES CENTER

A. SYSTEM CRITERION - Characterize your system using the following outline

1. TYPE

   a. Acoustic (nonstatic, histatic, time of arrival etc.)

   b. Electromagnetic (CW, FM, AM, pulsed, doppler, wavelength)

   c. Hit Indicator (type of panel or sensor)

   d. Other (describe)

2. REQUIREMENTS FOR SCORING

   a. Amplitude rise time

   b. Amplitude intensity

   c. Doppler curve match

   d. Physical contact

   e. Other (describe)

3. SCORING PRESENTATION TYPE

   a. Single zone

   b. Multiple Zone

   c. Continuous miss distance scalar

   d. Vectorial information

   e. Other

4. SCORING RANGE ________ FEET TO ________ FEET

   a. Fixed

   b. Adjustable (explain)

5. VECTORIAL COVERAGE IN ALL THREE PLANES

   a. Fixed

   b. Adjustable (explain)

6. METHOD OF CALIBRATING THE INDICATED VOLUME OF DETECTION

   a. Through actual use

   b. Special test equipment

   c. Other (explain)

7. CAPABLE OF SCORING PROJECTILE SIZES ____MM TO ____MM

   a. Without system adjustment

   b. With system adjustment to compensate for various projectile sizes

8. MAXIMUM SCORING RATE ______________ROUNDS PER MINUTE

9. SCORING ACCURACY FOR ALL DETECTABLE PROJECTILE SIZES

10. MENTION THE MIL-SPECIFICATIONS THAT ARE APPLICABLE TO YOUR SYSTEM.

11. APPROXIMATE SYSTEM PRICE

12. RELIABILITY IN TERMS OF MEAN-TIME-BETWEEN-FAILURES (MBTF) AND FREQUENCY OF CALIBRATION

13. ARE YOUR SYSTEMS CAPABLE OF MULTIPLE USAGE WHEN POSITIONED CLOSE TO ONE ANOTHER ?

14. TARGET HANDLING ABILITY

   a. Single

   b. Multiple targets of the same size

   c. Mixed targets

15. REJECTION TO FALSE TARGETS AND METHOD OF DISCRIMINATION FOR FLYING DEBRIS, MUZZLF BLAST, SIMULTANEOUS IMPACT, MOVING FOLIAGE, WIND NOISE LIMITATION, ETC.

16. VELOCITY LIMITATIONS FOR VARIOUS PROJECTILES

    a. Subsonic
    b. Supersonic
    c. Tumbling rounds

17. TOTAL SYSTEM WEIGHT AND DIMENSIONS

18. DELIVERY OF SYSTEMS IN QUANTITIES 10; 100; 1,000.

B. TARGET RANGE REQUIREMENTS

1. ELECTRICAL POWER NEEDED

    a. Voltage
    b. Frequency
    c. Continuous watts
    d. Momentary watts
    e. Duty cycle

2. PREPARATION OF THE RANGE FOR SYSTEM INSTALLATION

    a. Damage protection
    b. Geometry with respect to target
    c. Calibration technique
    d. Foliage clearance
    e. Mounting procedure

3. DESCRIBE ATTACK PARAMETER LIMITATIONS

    a. Azimuth
    b. Elevation
    c. Velocity of firing platform
    d. Range of firing platform

4. SPECIAL EQUIPMENT NEEDED FOR ON-SITE CALIBRATION OR RECORDING OF RAW DATA

C. TRANSMISSION OF RAW DATA

1. TELEMETRY

a. AM, FM deviation
b. Digital or analog
c. Carrier power
d. Frequency
e. Maximum range
f. Antenna configuration
g. Installation procedure

2. HARD WIRE

a. Coaxial
b. Twisted pairs
c. Maximum wire length
d. Impedance
e. Signal level
f. Installation procedure

D. SCORING READOUT

1. DISPLAY

a. Single or multiple counters
b. Recorders
c. Intercept history or miss distance and vector
d. CRT console
e. Numerical (feet, meters, degrees, etc.)

2. ELECTRICAL POWER REQUIREMENTS

a. Voltage
b. Frequency
c. Continuous watts
d. Momentary surge

3. INSTALLATION NEEDED FOR DISPLA. EQUIPMENT

4. SUITABILITY FOR USE IN VARIOUS ENVIRONMENTAL CONDITIONS

   a. Bright sunlight

   b. Night

   c. Moisture

   d. Sand and salt spray

   e. Other (describe)

E. CONSTRUCTION TECHNIQUES

1. MODULAR

2. THIN FILM

3. INTEGRATED CIRCUITS

4. OTHER

SURVEY

ARMED AIRCRAFT QUALIFICATION RANGE SCORING SYSTEM STUDY
FOR
NAVAL TRAINING DEVICES CENTER

A. Please provide list of applicable components manufactured by your firm:

   1. Complete data link systems including transmitter, transmission medium (hardware or telemetry, receiver, video processor (if any), display unit.

   2. Individual components including partial systems.

B. For either individual components or systems, list all parameters including frequencies, power levels, prime power required, size, weight, maximum expansion capability (to larger systems via modulator additions), data rate.

C. For individual components list interfacing information, i.e., VSWR's, maximum permissible loading, connector types, etc.

D. Please provide the cost per unit or per system for quantities of 1, 10, 100 and 1000, and the delivery times available. The cost and delivery must include the effects of compliance with MIL-STD-461, "Electromagnetic Interference Characteristic Requirements for Equipment"; and MIL-STD-470, "Maintainability Program Requirements (For Systems and Equipment)".

E. Information which you might possess relating to shock and vibration limits of your equipment would be helpful in evaluating the total environment.

F. Your data should include construction methods which you use; such as modular, thin film, integrated circuits.

APPENDIX C

WATER RANGE CONCEPT

APPENDIX C

WATER RANGE CONCEPT

A. DESCRIPTION

During the period between the first and second conferences, the feasibility of a constructed water range in lieu of existing land ranges was considered as part of the study. A water range would have many advantages over land ranges and would alleviate many of the problems inherent to land ranges. The primary advantage of the water range is that the spectacular splash effects, even from inert projectiles would provide the instructor pilot with a greatly improved reference for observing the footprint of multiple-round bursts or the entry point of individual rounds, thus aiding in his evaluation of student firing accuracy. Other advantages of a water range in comparison with land range are:

* No flying debris (increased safety for low flying gunships),
* Range boundaries permanently marked by shoreline,
* Elimination of fire hazards,
* Danger from unexploded charges or unburned rocket engines eliminated, or reduced,
* Flechette impacts marked,
* Tributaries provide possible secondary ranges, and
* Possibility of future use as wildlife refuge.

The water range concept includes the use of TV camera systems installed in the gunships to supplement instructor scoring of 2.75-inch rockets. The TV system would record both helicopter attitude data and projectile impact point for post-gunnery evaluation. This additional scoring device was considered valuable because the rocket is the most difficult projectile to learn to fire and because of its relatively high cost compared to other projectiles.

A map of a proposed water range at Fort Rucker was provided by the Department of Agriculture. By constructing a dam across existing natural waterways a primary water range 800 by 6,000 meters in size would result. Several tributaries 1 kilometer in length would also exist which might be used as secondary ranges. While no preliminary plan for a water range at Fort Stewert was made, the area is swampy with a high water table so that no difficulty is foreseen.

B. CUSTOMER COMMENTS AND EVALUATION

The water range concept was discussed with Army personnel at both Fort Rucker and Fort Stewart and later with NTDC representatives. Two possible disadvantages were expressed by Army personnel; it was believed that (1) there might be a problem in pilot depth-perception over water ranges, and (2) that ricochet effects might be worse than those incurring to a land. After some consideration, it was concluded that the depth perception problem would not be serious as the water plane could be broken up with realistic-sized targets and other visual reference devices which would provide the necessary depth perception. Because the range proposed would be less than 1000 meters in width, the proximity of the shore itself would also provide visual reference.

The ricochet effect was subsequently discussed with M. Reche of BRL who is presently conducting an analytic study on this subject. His findings, as applied to the water range are as follows:

* In general, ricochet effects would be the same on water as on land.
* Ricochet would be the same for all munitions.
* At entry angles greater than 12 degrees, there is very little ricochet.
* At entry angles less than 12 degrees, the maximum exit angle is approximately 15 degrees.

From this information it was concluded that under the worst conditions, the ricochet effect would be no more serious than on land, and since the water range would be naturally at some lower level than the surrounding land, some ricochets would be stopped by the higher surroundings, thus affording some improvement over land ricochet effects.

The advantages and disadvantages of the water range concept were discussed in detail with NTDC representatives at the second technical conference. The chief disadvantage of the concept appears to be the continued use of the instructor pilot as a scoring device. It is recognized that, as with the existing scoring method, 100 percent scoring reliability is achieved, but scoring accuracy is still in question. Sanders believes that the improved visual display obtained from the water range should increase instructor scoring accuracy, but no numerical value for this quantity is presently available.

A second possible disadvantage of the concept pertains to the splash effect itself. The amount of splash produced by a ricocheting projectile is unknown. Tests would have to be conducted to determine the visibility of impact for a ricocheting projectile. In addition, the effect of wind and resulting waves might lower the visibility of projectile impact. This also would necessitate testing.

During the conference various questions were raised by NTDC representatives regarding the water range concept. These questions and the answers given by Sanders Associates personnel are as follows:

Q. Would a water range increase the hazard to pilots if a forced landing were required?

A. Force landings are always hazardous at low altitudes whether over land or water. Since the width of the range would be relatively narrow (2,000 f[illegible] possibility exists that the gunship could m[illegible] to the shore or at least to shallow water. If a water ditch were necessary, the water should provide a softer "cushion", but the standard procedure (90-degree roll) would probably be required.

Q. What type of targets would be employed, would target disintegration contaminate the water, and how would targets be anchored?

A. Targets would be made of lightweight plastic, possibly water soluble, and would simulate real targets in shape and in size (the latter to aid in depth perception). Flotation would be accomplished by lightweight material, possibly balsa wood which would be anchored below the surface. The targets would have to be anchored at two points to keep them in a plane perpendicular to the attack corridor.

Q. Would movement of targets under windy conditions prove to be a problem?

A. It is believed that small movements permitted by slack in the anchorage would be almost unpredictable at the firing ranges specified.

Q. Would instructor scoring accuracy decrease at low attack angles due to optical illusion; i.e., round passing through the target -- a hit -- would produce a splash beyond the target indicating a near miss?

A. The instructor might have somewhat more difficulty in scoring longitudinally displayed rounds, at low attack angles. He would have to count all splashes within a certain distance behind the target as hits.

Q. How would the range safety area around the water range be selected?

A. Current procedures for establishing range fans would be followed to conform to the outlines of the water range. All non-standard range boundaries must be approved by USAMC.

Q. Would realism be reduced with the use of a water range?

A. Sanders maintains that true combat realism can only be achieved in actual combat areas. There is target realism and target environmental realism. While target realism is not difficult to simulate, no gunnery range which is used extensively will exhibit target environmental realism for very long.

C. COST ESTIMATE

Two cost estimates were obtained for a water range. The Alabama Department of Agriculture estimated the $150 to 250K would be required for construction of dam and lake at Fort Rucker. This would provide a 6 kilometer range covering about 900 acres with tributary ranges. A second estimate from the Corps of Engineers provided an estimate of $100K for a 3 kilometer range.

Additional costs would be incurred if television monitoring systems were used on rocket launching gunships as a supplement to instructor scoring for 2.75-inch rockets. It is estimated that approximately $100K would be required per system; this would include cost of camera, transmitter, receiver and monitor.

D. SUMMARY

It is suggested that for qualification purposes, the water range might offer an alternate approach for the AAQRSS in terms of economy and overall training efficiency. The concept would employ the instructor pilot for most scoring requirements and the possible use of TV cameras installed in some gunships for recording the helicopter attitude at the time of rocket fire and the resulting rocket impact point. The ease of visual strike analysis on the water would reduce the need for sophisticated electronic scoring system which would inevitably require maintenance and repair. Table 6 provides a comparison of water and ground ranges in terms of the type of projectile used. It can be seen that when using either type of projectile the water range has definite advantages.

TABLE 6. COMPARISON OF GROUND RANGES VERSUS WATER RANGES AS A FUNCTION OF TYPE OF PROJECTILE USED

Criteria	Ground Range (live projectiles)	Water Range (live projectiles)	Ground Range (inert projectiles)	Wator Range (inert projectiles)
1. Visibility of Projectile Impact	fair	excellent	poor	excellent
2. Environment for Scoring System	very poor*	fair	good	excellent
3. Range Boundary Stability	poor	excellent	fair	excellent
4. Elimination of Fire Hazard	very poor	excellent	good	excellent
5. Range Safety	very poor	good	excellent	excellent

*For targot-mounted sensors. For standoff sensors, environment is good.

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11. SUPPLEMENTARY NOTES Report on Scoring Systems for Helicopter Gunship Ranges	12. SPONSORING MILITARY ACTIVITY Naval Training Device Center Orlando, Florida

13. ABSTRACT

This study examined existing objective scoring devices, scoring systems under development, and possible new techniques, for suitability of application to an Armed Aircraft Qualification Range Scoring System to provide feedback to, and evaluation of, helicopter gunnery students. The current training program, training facilities, and scoring techniques were also evaluated as background information for the study.

Results indicate that scoring systems under development, and most existing scoring devices, are not capable of rapid fire air-to-ground scoring; furthermore, no system delivers vector data on rounds scored. A new technique, the water range concept, has merit as an inexpensive, reliable, maintenance free approach to scoring, but fails to satisfy many specific design requirements. Radar and acoustic systems which depend on a sensor located at the target are unreliable because the sensor is highly susceptible to being destroyed or damaged by the projectiles to be scored. A radar system, which uses a standoff sensor in front of the target, offers the only prospect for a reliable and accurate scoring system. Since the system would not provide vector data, [illegible] observation technique would also be required to [illegible]

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Scoring System						
Projectile						
Radar						
Acoustic						
Water Range						
Accurate						
Reliable						
Motivation						
Antenna						
Instructor Pilot						
Student						
Zones						
Miss Distance						
Vector Information						
Standoff						
Telemetry						
Hardwire						
Display						
Sensor						

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DESCRIPTORS

Scoring System
Aerial gunnery
Gunnery training
Ranges (Facilities)
Instrumentation
Armed aircraft qualification range scoring system
Radar scoring system

Sanders Associates, Inc.
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